DOCUMENT RESUME

ED 325 329 SE 051 665

AUTHOR	Hulland, Carol Marie
TITLE	Multiple Perceptions of Science Concepts: A Qualitative Study in a Swamp.
PUB DATE	90
NOTE	203p.; Master's Thesis, Queen's University.
PUB TYPE	Dissertations/Theses - Master Theses (042)
EDRS PRICE	MF01/PC09 Plus Postage.
DESCRIPTORS	*Cognitive Development; Cognitive Processes; *Concept Formation; Curriculum Guides; Ecology; Elementary School Science; *Ethnography; *Grade 5; *Information Processing; *Intermediate Grades; Learning Strategies; Misconceptions; Schemata (Cognition); Science Education; Thinking Skills
IDENTIFIERS	*Constructivism

ABSTRACT

This study focuses on how students make sense of and understand concepts related to the study of a wetland. The analyses of students' talk and drawings recorded during a 2-week wetland unit were divided into two levels. The first level examined students' understandings and explored student traits that contributed to a clear, stable understanding of the wetland environment. Students' ideas seemed to fit patterns, which were categorized and discussed as strongly held ideas, developing ideas, easily altered ideas, and contradictory or confusing ideas. The second level of the analysis examined two of the students' sense-making processes, termed respectively a "scientific" process and a "storytelling" process. How students made sense of information seemed to be related to what they understood about the wetland. By providing a context within which students' actions could be observed and analyzed, the wetland study obtain information about how students' talk and play developed as their experience with concepts increased. Appended are copies of: (1) the consent form; (2) wildlife pictures; (3) metaphor interview; (4) teacher hand-outs; (5) curriculum outline; (6) field notes; and (7) student drawings. (KR)

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MULTIPLE PERCEPTIONS OF SCIENCE CONCEPTS:
A QUALITATIVE STUDY IN A SWAMP

by

CAROL MARIE HULLAND

A thesis submitted to the
Faculty of Education
in partial fulfillment of the requirements
for the degree of Master of Education

Queen's University
Kingston, Ontario, Canada
May, 1990

SE051665

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ACKNOWLEDGEMENTS

I would like to thank my thesis supervisor, Hugh Munby for his conscientious support of my work. He has provided me with excellent guidance and swift responses to all work handed to him.

I would also like to thank the other members of my thesis committee, Jeff Bloom and John Olson. Their criticisms have provided me with a broader perspective upon which to critically analyze my own work.

Skip Hills provided me with an opportunity to join the "Science Club" in Frontenac County. I am very happy to have become involved in such an enthusiastic and effective group promoting science education at the elementary level.

Many of my graduate student colleagues have also provided me with support as I have worked on the thesis. My thanks go especially to Megan Aston for her encouragement and criticisms.

Although I can not name them, I would like to thank the camp administrators and their staff who accommodated my study into their summer camp program. Above all, I would like to thank the six students who so enthusiastically participated in the study.

Since I believe in recycling, many pages of drafts have ended up in my current classroom as scrap paper. I would like to thank my 25 copy "editors," who have enjoyed having the opportunity to "edit" my work for a change.

On a personal note, there are four people I wish to thank. Thanks to Harmony, my Little Sister, who has been very tolerant when I cut into our time together to finish my work.

My parents have always supported my academic endeavours, listened to me when I've been enthusistic and kept me going when I wasn't.

Finally, I wish to thank my husband, Steve Strugnell, for his support, for his understanding when I hog the computer, and mostly, for his patience with me.

ABSTRACT

The thesis is a qualitative study in science education, focussing on how students make sense of and understand concepts related to the study of a wetland. Six grade five students' talk and drawings recorded during a two week wetland unit formed the basis for the analysis. The analysis was divided into two levels. The first level of the analysis examined students' understandings and explored student traits that contributed to a clear, stable understanding of the wetland environment. Students' ideas seemed to fit certain patterns, which were categorized and discussed as strongly held ideas, developing ideas, easily altered ideas, and contradictory or confusing ideas.

The second level of the analysis examined two of the students' sense making processes, termed respectively a "scientific" process and a "storytelling" process. How students made sense of information seemed to be related to what they understood about the wetland. The student who used a "scientific" sense-making process provided unambiguous, clear and general explanations for events occurring in the wetland. The student who used a "storytelling" sense-making process provided personal stories, using factual information as part of the story. Her explanations for events were sometimes contradictory, and they were specific to individual situations. She did not seem to have a stable, clear perception of the wetland

environment.

By providing a context within which students' actions can be observed and analyzed, the wetland study supplies information about how students' talk and play develops as their experience with concepts increases. The wetland study is important for two reasons. First, as a sustained study of a group of students, it creates a framework for studying how students make sense of science concepts over time. Second, as a study developed and administered by a classroom teacher, it provides support for perspectives gained through research by a teacher within the classroom.

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CHAPTER 1

EXPLORING CHILDREN'S UNDERSTANDING: AN OVERVIEW

Preparing the Grounds for the Thesis

Few studies in science education research have observed how a group of students make sense of a set of related concepts over a period of time. Aguirre and Kuhn (1987) observed students throughout a month long unit on radiation and nuclear energy but the focus of their study was to examine the characteristics of instruction that encourage students to construct knowledge as they learn. Bloom (in press) analyzed students' talk about their understanding of an unfamiliar concept but he interviewed each student only once. Other studies (Snively, 1983; Gilbert, Watts & Osborne, 1985) have used different methods for interviewing students to analyze their understanding about specific concepts but few studies have examined how students make sense of specific science concepts over a period of time.

The current study provided six grade five students with opportunities to make observations about and to explore a wetland environment daily during a two-week unit. The study, termed the wetland study, was designed to examine not only what students understood about the wetland environment but also to examine how they made sense of their observations.

The thesis is based on a qualitative study of a learning situation. The purposes for the study are linked to my experiences as an elementary science teacher. I am concerned about how students sometimes seem to make little sense of scientific principles. If, as a teacher, I know more about how students make sense of information relating to specific concepts and can recognize a pattern to students' development of understanding, then it may be possible to better meet students' needs by providing them with tools to help them effectively extend their understanding.

Purposes of the Study

The primary purpose of the current study is to explore how students make sense of concepts related to the study of a wetland environment. The secondary purpose of the study is to assess the value of several methods used to collect data in an ethnographic study in which the instructor is also the primary observer. The research questions addressed by the primary purpose are:

1. How do students express their understanding of the wetland environment throughout the unit?
2. What are the common characteristics of the students' talk about the wetland environment?
3. What processes do students use to make sense of concepts?

Research questions related to the secondary purpose are:

1. Which methods produce the most robust data?

2. What are the strengths and limitations of each method?

The sixth chapter of the current thesis reviews the study and assesses how successfully each of these questions has been answered.

Outline of the Study

The theoretical framework for the current study outlines several research perspectives that have been used to examine students' understanding. The wetland study overlaps several areas of research. Ideas about the nature of science, about science education, about cognitive psychology theories, about reflecting on experience to become expert, and about the role of language in structuring thinking form the basis of the literature review, found in chapter 2.

Science educators have expressed a great deal of frustration about students' resistance to accepting a scientific way of thinking (Linn, 1987; Driver & Bell, 1986; Champagne & Klopfer, 1984). Several researchers have suggested that identifying students' misconceptions can allow new curriculum to be designed that can change students' understandings (Arnaudin & Mintzes, 1985; Wandersee, 1985; Gil & Carrascosa, 1987). That seems to be only a partial solution. Information processing theory suggests that before students can be convinced to think as scientists it is important to understand what is creating their resistance to change.

Schema theory, which suggests that people create new knowledge by using their existing knowledge base to make sense of observations, is suggested as a feasible model for explaining how students' perceptions of concepts can be different from scientists' perceptions (Champagne & Klopfer, 1984; Osborne, Bell & Gilbert, 1983). Information processing theory provides a useful way of thinking about how students create knowledge. The literature review in chapter 2 suggests another view about how people make sense of events, looking at how our use of language structures our thinking. Differences between everyday uses of language and scientific uses of the same language are suggested to create a cultural barrier that students find difficult to cross (Hawkins, 1978; Hawkins & Pea, 1987; Osborne, Bell & Gilbert, 1983).

The thesis has been divided into six chapters. The second chapter provides a rationale for the study. Reasons for choosing to observe students' responses to a task for two weeks as an instructor are discussed and supported by a theoretical framework in chapter 2. Chapter 3 describes the setting for the study, the curriculum outline and all data collecting methods. Since the analytical framework was created as the data was collected and examined, the genesis of the analysis is described as part of the methods chapter.

Two chapters have been devoted to presenting the analysis of the data. The analysis developed into two levels with a common purpose--to comment on how students understand information. The first chapter of the analysis, chapter 4, suggests that students' prior experiences, their ability to use language to clarify ideas, and their confidence in their own knowledge can affect how they understand ideas. Students' ideas have been categorized into four groups--strongly held, developing, easily altered by observation and contradictory or confusing ideas--to provide a framework for comparing and discussing students' understandings.

Two of the students in the group were found to have very different perceptions from one another about the wetland environment. These two students are discussed in the second chapter of the analysis, chapter 5, examining the processes two students used to make sense of their observations about the wetland. Although both students played with materials and talked about their ideas as they sought to make sense of information, one student seemed to use a more effective process for linking ideas. The two types of sense making processes are termed a "scientific" process and a "storytelling" process.

The "storytelling" process involved creating metaphors and stories to make sense of the wetland environment while the "scientific" process involved making hypotheses about problems based on clues in the environment, and testing the hypotheses as far as possible. The analysis suggests that a student who makes sense of information by weaving it into stories may understand individual events in different ways while a student who makes sense of information by searching for clues to support his or her current knowledge may understand that events are related, and may seek consistent explanations for events.

The final chapter of the thesis summarizes the study, assesses the value of each data collecting method used and answers the research questions presented above. Individual interviews, and tape recorded sessions are suggested to be the most useful data collecting methods. The effectiveness of several interview techniques derived from other studies is discussed.

Implications of the wetland study are discussed in chapter 6. The wetland study provides evidence to support some parts of the current theoretical understandings about how students make sense of information. The study indicates that students need to manipulate materials and to talk about their ideas. It also suggests that more qualitative research studies are needed in the area of science education to observe how students' understanding develops about specific concepts over a period of time. Chapter 6 ends with comments about the study's design, and questions appropriate for a follow-up ethnographic study, to be done by a teacher.

CHAPTER 2

CHILDREN'S UNDERSTANDING: A CONCEPTUAL FRAMEWORK

Rationale

As an elementary science teacher I am curious about how my students learn and I am concerned about students who seem to be constantly frustrated by the process of learning. In spite of efforts to improve the success of science education programs, children's ideas about scientific phenomena have been found to often be idiosyncratic and resistant to change through education (Champagne & Klopfer, 1984; Linn, 1987).

Students' resistance to change through education is not only frustrating as an educator but also potentially dangerous. There is a realization that we need to rapidly change how we think about the earth if we are to survive much longer on this planet. Educators can play an important role in shifting cultural perceptions about the environment. If we know how students' understandings about the world affect how they make sense of new information, then perhaps we can find ways to challenge students' basic views and affect real change in their perceptions of the world.

Several interpretations based on a variety of theoretical frameworks have been developed to explain how students make sense of data and how their perceptions about the world may affect their understanding. The current thesis makes reference to several research theories explaining students' sense making processes. These theories are discussed in this chapter.

The literature review has been divided into five sections. The first section considers the nature of science and how science is often perceived as a discipline. The second section discusses findings in science education literature explaining students' alternative conceptions of science information. Differences between the cultures of science and of everyday living are discussed. Strategies being used to make sense of students' alternate conceptions and to encourage them to adopt a more scientific approach are also considered. The third section discusses the role of cognitive psychology research in examining how students construct knowledge.

The fourth section of the chapter discusses the value of reflecting on one's understanding about events and considers the importance of language and play in students' attempts to make sense of unfamiliar ideas. The last section discusses reasons for using an ethnographic research design in the current study and some considerations to be made within a qualitative study.

The Nature of Science

The first section of the literature review briefly examines the nature of science and how it is thought about by teachers as the purveyors of science education. The argument suggests that the view of the world presented through science education must be recognized by teachers as an inescapable influence on their teaching. Students' views of the world are considered within the second section of the literature review, dealing with alternate conceptions.

One of the most powerful influences on the perception of what should be taught in science comes from the world views of those involved in the education process. A world view provides a conceptual structure which incorporates an individual's knowledge and experiences about the world into a sensible, meaningful model. Kilbourn (1980a) suggested, with reference to Pepper (1942), that one's world view is so intimate and pervasive that its effects on one's actions are enormous but often unsuspected. Kilbourn (1980a) pointed out that the hidden, or even subconscious message relayed to students by the teacher can block the students' awareness that there can be other ways of viewing the world.

Munby and Russell (1983) and Kilbourn (1980a) agreed that the model upon which science education is currently based is that of a metaphysical machine. A mechanistic view of the world assumes that events are predictable and generalizable, and that causes can be linked to effects. If scientific thinking is linked only to a mechanistic model within school science, then acceptable ways of thinking about events are limited. Such a view is troublesome because it can contribute to problems in increasing students' success in science education. In spite of instruction, many students maintain their own sense making system about the world, rejecting the teacher's view that a scientific perspective would be superior. Driver and Bell (1986) pointed out that, in fact, students often interact with experiences in their own ways and that they can learn different things from the same experience.

Hodson (1986) took a number of examples of figures used in psychology to illustrate that observations about the world are dependent upon the viewer's experience with the data, upon previous knowledge of the figures, and upon the context in which the figures are presented. Goldstein and Goldstein (1978) argued further that observations about similar events can lead to widely varying conclusions based on cultural understandings about events. Cultural understandings, including cultural differences between scientists and non-scientists, colour the context within which an individual perceives events.

The effect of context on perception is not accounted for within a mechanistic world view. Roberts (1982) suggested that widely opposing views--those that deal with the mechanics of events, as opposed to those that deal with the context within which events occur--can provide equally sound arguments to explain situations. Although he was examining ways of approaching research in science education, the argument also seems to be appropriate to the discussion about the nature of science itself. The difference between ways of arguing rests in the backing provided to support the argument. If events appear to be causally related and evidence of causation proved, then a mechanistic view can provide a plausible explanation for observed events. Often events are not logically or evidentially linked. In some cases, events may be better explained by recognizing that they must be viewed within a particular context.

A mechanistic view and a contextual view of the world and of science in particular can be complementary. Different world views can explain the same phenomena, in ways that make sense to individuals who approach the problem with different knowledge bases and a range of experiences. This issue will be referred to later in the thesis, during the discussion of the results of the study. The next question to be considered in the literature review is how successfully students' explanations can describe the environment for another person. The basis for asking the question has roots in the "misconceptions" literature.

Misconceptions Literature

"Misconceptions" literature within the current discussion refers to a number of research findings with two common features. First, they all acknowledged that students enter science education programs with a well established world view. They recognized that students make selective observations about the world and organize information in ways that make sense based on their understanding about the way the world works (Fisher & Lipson, 1986; Linn, 1987; Hawkins & Pea, 1987). The second common feature of all the papers was recognition that it is extremely difficult to change a student's interpretation of events.

The major differences between researchers' views can be illustrated by the language they use to describe learners. Two approaches to explaining students' inability to accept a scientific conception of events are discussed below. The first group classed students' non-scientific understandings as errors, or as misinterpretations of information while the second group examined non-scientific understandings as failures to adopt the culture of scientific thinking and inquiry.

Studies Focussing on Student Errors or Misinterpretations

Discussions about student errors in science can be presented either as an issue encouraging students to reflect upon their work or as an issue encouraging educators to reflect upon the curriculum. Fisher and Lipson (1986) suggested that student errors can be used as a means of improving students' ability to assess their own work. In contrast, a number of researchers discuss students' "misconceptions" as a problem related to curriuclum, with responsibility for change being left to educators. Fisher and Lipson's research is discussed below, followed by a selection of reports suggesting curriculum changes to improve science education.

Fisher and Lipson (1986) recommended analyzing students' errors in science as an effective means of discovering root causes of students' misunderstandings. Errors, they contended, are an essential part of the culture of science. Students should be able to use errors as opportunities to critically assess their own work and to learn how to avoid the problem in the future. As a teacher, I like Fisher and Lipson's view. Students seem to be willing to risk more if they recognize that it is, in fact, a part of science learning to make mistakes. Acceptance and assessment of errors may be one important factor in challenging students' non-scientific conceptions, but the approach assumes that a certain level of enculturation into the world of scientists already exists. A cultural barrier between scientific and everyday thinking is described below.

Many researchers seemed to suggest that it is the educator's task to alter children's perspectives. Several science education research reports offering suggestions for changing science curriculum are reviewed below (Arnaudin & Mintzes, 1985; Perez & Carrascosa, 1987; Wandersee, 1985; Gilbert, Watts & Osborne, 1985). Common features of the reports were that they all discussed the need to change students' ideas about scientific events and they all focused their assessment on students' concepts of one narrow issue in either life sciences or physical sciences. Perhaps the most important feature to note is that they all presented students with a series of direct questions requiring simple answers that could be statistically analyzed and readily compared with other students' responses.

Arnaudin and Mintzes (1985), and Wandersee (1985) compared students' responses across grades. Based on their findings, they both suggested that as children get older, some of their ideas progress toward scientific ideas while other concepts are resistant to change. As an example, Arnaudin and Mintzes (1985) discovered that students' understanding about the function of blood shifted from an elementary school understanding that blood keeps people alive, to a more advanced understanding that blood carries oxygen and nutrients. On the other hand, students' ideas about the structure of blood remained relatively constant from elementary school through college level.

Wandersee (1985) found that as students progressed through school, they tended increasingly to choose explanations about photosynthesis from a selection of historical understandings that fit the currently accepted explanations. Some concepts were easily shifted while others led to only a small increase in the number of students adopting the accepted scientific explanation with increasing grade. Both studies (Arnaudin & Mintzes, 1985;

Wandersee, 1985) provided recommendations for improving science curriculum, based on methods tested in the study. There seems to be an implicit yet unproven claim in both studies that their suggestions for curriculum development can alter students' understanding and improve science education.

Two of the papers (Gil & Carrascosa, 1987; Wandersee, 1985) suggested that students' common sense responses reflect the historical misconceptions of scientists studying, respectively, the principles of mechanics and photosynthesis. Students were found, in both studies, to provide answers that supported common sense conclusions about problems, rather than agreeing with current scientific theories. Gil and Carrascosa also found that both students and teachers tended to answer questions quickly, limiting the amount of time spent reflecting on the problem.

Both Gil and Carrascosa (1987) and Wandersee (1985) recommended including a history of science in science education courses as a means of reducing students' "misconceptions." The discussion in both studies was unsettling because neither one explained how introducing students to historical errors in science would increase students' ability to interpret events from a scientific perspective. Furthermore, Wandersee's data suggested that students did not always move from disproven historical theories to accepted theories even after instruction.

Gil and Carrascosa (1987) suggested that historical evidence could shift students' understanding, but they showed that the number of incorrect responses students offered about mechanics questions remained relatively constant, or even increased with age. No evidence has been provided to support the claim that introducing students to historical errors in science can increase students' selection of currently acceptable scientific theories.

There may be some relevance to the notion that students should understand something about the history of science, but neither Gil and Carrascosa nor Wandersee (1985) presented evidence to indicate how an introduction to the history of science could increase students' success in understanding scientific principles. Part of the problem may be that the studies reviewed above used multiple choice questionnaires to determine students' ideas and did not encourage students to talk about their understandings.

Studies conducted by Gilbert, Watts and Osborne (1985) were similar in some ways to the studies described above in that students were shown a series of pictures related to a physical principle and were asked questions answerable with "yes" or "no." In addition to the simple questioning, however, students were asked to explain their responses. The technique, termed an Interview-about-Instances (IAI), was used to explore students' use of language about physical phenomena.

The IAI technique provided for Gilbert et al.(1985) a context within which to explore the culture of students in science classes. Discussion about students' use of language to describe scientific phenomena provides the basis for the next part or the literature review, exploring the differences between students' culture and scientists' culture.

Failure to Adopt the Culture of Scientists

Osborne, Bell and Gilbert (1983) outlined differences between children's science, which they refer to as "children's attempts to make sense of the world," and scientist's science. Scientists, they suggested, are capable of abstract reasoning that is difficult for children as they struggle to understand the immediately surrounding world. Children base their understandings about the world on their own experiences and tend to search for specific explanations for events even if this means contradicting an earlier explanation given in a similar situation. Scientific understanding often goes beyond a child's experience. Children can have a difficult time recognizing a need for coherent, non-contradictory explanations for events.

Another difference separating children's culture and scientists' culture involves a language problem. Although many of the same words are used to describe everyday situations and scientific events, scientific explanations require much more precise definitions. Osborne et al. (1983) argued that children, being exposed more to the everyday uses of language than to its scientific uses become increasingly resistant to the linguistic precision required to understand and to explain events as a scientist. They suggested that there can be greater cultural similarities in the understanding of concepts across international borders than across the border between everyday and scientific thinking.

Hawkins (1978) expressed concern about the seemingly unbreachable culture gap between common sense and science. He argued that the bridge between the cultures involves increasing students' understanding of elementary scientific principles. These fundamental principles are seen as the basic units upon which all other understanding of science events can be structured. Hawkins' (1978) outlined several issues students often find difficult to understand, such as principles of size and scale. He termed these difficult concepts as "critical barriers" to scientific understanding. Hills and M^cAndrews (1987) elaborated on Hawkins work, suggesting that students and teachers can cross critical barriers by spending time observing and talking about scientific phenomena presented in unusual ways.

How can the language barrier between everyday and scientific understanding be bridged? Several science education researchers have taken steps to explore the problem. Their work is discussed within this section. Discussion of the role of language in developing an understanding of scientific principles overlaps with several areas of research. In a later section of this chapter the issue of language as a tool for sense making is approached from a cognitive perspective. The present discussion focuses specifically on the function of language in science education.

One of the greatest differences between everyday language and scientific language is the level of precision required to explain concepts (Hills & McAndrews, 1987; Hawkins & Pea, 1987). Everyday language is rich with metaphors that provide adequate images to make sense of events but when analyzed closely, they often present contradictory, incoherent explanations of events (Hawkins & Pea, 1987; Osborne, Bell & Gilbert, 1983). Hawkins and Pea (1987) suggested that one of the common features of everyday language and science language is the use of explanation. Teaching students to use language precisely in explanations may be an essential step in bridging the gap between the language of science and everyday language.

Studies examining children's oral language suggested that there is a great deal of redefining of terms as children consider new information about observations. Solomon (1983) suggested that students can adopt scientific explanations for events if they are taught using a mixture of scientific and everyday language. Osborne et al. (1983) argued that teachers often present a confusing mixture of children's science concepts mixed with textbook science terms. Children's science, they contended, cannot be ignored, but should be recognized both by the teacher and the child as a structure of ideas that must be challenged.

When children are presented with an unusual situation and are asked to talk about it, they seem to create meanings (Bloom, in press). Bloom suggested that students draw on other familiar concepts to create meaning about and explanations for an unfamiliar observation. When children were presented with a container filled with earthworms and asked to talk about it they seemed to seek associations between their experience and previous knowledge. Bloom also found that students created metaphors to describe the worms.

In other work (Bloom, 1990), students were asked to create context maps. Context maps required students to link all their ideas about one topic, such as world issues, using words and pictures. Follow up interviews with the students allowed them to talk about their context maps and to explain their thoughts. Bloom's methods allow children to talk about their beliefs but capture only a moment of the child's thoughts. There seems to be a need to explore how students' thoughts can develop and be used to create a bridge between everyday language and the language of science. The next section of the literature review, identifying students' thought processes moves into information processing theories.

Cognitive Psychology Research Describing Sense Making Behaviour

Questions about how learners make sense of information provide the basis for many research projects in the fields of science education research and information processing research. The work of many researchers overlaps the two fields (Champagne & Klopfer, 1984; Resnick, 1983; Carey, 1986; Osborne & Wittrock, 1983; Posner, Strike, Hewson & Gertzog, 1982). This section of the literature review outlines features of cognitive psychology research that offer valuable insights into science learning.

The section begins with an overview of schema theory, followed by a discussion of current views held about processing and accessing information. The section ends with ideas about how students can accept data inconsistent with their apparent understanding of scientific principles and comments about differences between novice and expert information processing.

Defining Schemata

Two major types of knowledge occurring in memory have been defined--procedural knowledge, referring to knowing how, and declarative knowledge, referring to knowing that. A schema refers to a knowledge structure in memory which allows declarative knowledge, sorted by categories and relationships, to be retrieved from long term memory (Champagne & Klopfer, 1984). Schemata provide the learner with expectations about what will happen within a particular situation (Anderson, 1984; Bransford & Johnson, 1972). Bransford and Johnson (1972) demonstrated, using a series of seemingly non-sensical passages, that if the context within which information is presented is obscure then learning is likely to be slow and uncertain. They argued that in the absence of a familiar context the learner could have trouble assimilating information into an existing schema.

For some learners, the context within which science concepts are presented may be obscure. Champagne and Klopfer (1984) have observed that students sometimes associate science information with schemata other than those intended by the teacher. They have found, for example, that while students may accept the laws of Newtonian mechanics in one situation, they may not be applied to other situations.

As has been discussed above, students' conceptual frameworks for understanding data can be extremely resistant to change through instruction. What does information processing research offer for improving science education? Three approaches are discussed below. First, it may be possible to change a student's perspective on a problem.

Second, students' problem solving experiences may assist in modifying existing schemata. Third, it may be possible to facilitate students' access to knowledge stored in memory.

Processing and Accessing Information

Differences in perspective often provide the basis for humour in our society. Children enjoy, for example, the adventures of Amelia Bedelia who does many silly things as she responds inappropriately to literal interpretations of terms. I think that children enjoy the humour because they sometimes find themselves holding a view that is not the perception expected or accepted by the teacher. Shifts in perspective may involve showing a picture to create a context through an image (Bransford & Johnson, 1972) or providing an additional piece of information to use as a hint or clue to the expected context (Anderson, 1984; Bransford, Sherwood, Vye & Rieser, 1986).

Anderson and Pichert (1978) found, in a study asking university students to read a description of a house, that details were most clearly recalled when the information was considered to be important based on a particular perception. When subjects were prompted to change their perception of a problem, from a burglar to a prospective housebuyer, a different set of important details could be retained from the same description. After a period of time, unimportant details were found to disappear and to become irretrievable from memory.

Finding ways of changing students' perceptions about science problems may be one way to increase the success of information recall. Resnick (1983) has suggested that without appropriate schemata to organize and structure knowledge, information is forgotten or at least inaccessible to memory.

Improving students' skills as problem solvers may be a second way of increasing students' development of appropriate schemata for assimilating science information. Carey (1986) and Larkin and Rainard (1986) have suggested that with increasing expertise, new relations between concepts become obvious, creating new schemata appropriate for solving problems. The process continues as new problems arise and schemata are developed and modified to solve the new current problems. Shifting from a novice problem solver to an expert is discussed in the next section of the literature review, focussing on the learner as a reflective problem solver.

Larkin and Rainard (1984) have identified three components of a problem solving model. The first is a representation of the problem solver's current knowledge about the problem. The representation can take several forms, depending on the problem solver's choice of and ability to use a variety of communication tools.

Gardner and Hatch (1989) maintained that the communication of intelligence in schools is largely limited to logical-mathematical and linguistic formats. They suggested that assessment of students' ability in school, including their ability to solve problems, should allow students to explore a multitude of intelligences. Larkin and Rainard (1984) have limited the current problem solving model to logical-mathematical and linguistic intelligences. Linguistic knowledge is the primary form of communication used in the current thesis as well.

The second component of Larkin and Rainard's (1984) problem solving model is a set of rules for building representations of problems. Each rule describes an action associated with a condition describing when the action is correct or useful. This second component of the problem solving model allows an assessment of the consistency of the problem solver's current knowledge with the conditions set in the problem. The third component of Larkin and Rainard's (1984) model involves an interpretation of how the rules apply to the problem. As new conditions are added to the problem situation, an interpretive process checks that the rules still match the conditions set by the problem representation. A novice problem solver can be guided to check the validity of steps in the problem representation.

Larkin and Rainard (1984) recommended that the problem solving model may be useful in explaining what students are doing when there is some confusion or resistance to instruction. Although the model has been developed using protocols collected in physics and mathematics, it seems to provide a general model for examining and comparing students' talk about problem situations encountered within a wetland environment.

Students can approach problem situations in different ways and with different results. Bransford, Sherwood, Vye and Rieser (1986) suggested that one of the greatest differences between more and less successful learners is their relative ability to identify problems, to develop and act on a strategy and to analyze their results. More successful students, they suggested, are able to revise their hypotheses and test alternate strategies. Students' representations of problems presented within the wetland study and their approaches to solving problems are discussed in chapter 6.

A third area in which information processing theory can help provide solutions to problems encountered in science education research involves exploring ways of facilitating access to information stored in long term memory. Bransford et al. (1986) compared methods of accessing information based on the hypothesis that if students considered knowledge useful only in the classroom, they would not recall it as well as if they could see applications to their own lives.

When college students were divided into two groups studying attention, one half studied strategies and techniques while the other half was encouraged to think about lapses of attention (Bransford et al., 1986). Recall of information was much greater in the latter group after two days, indicating that data which was related to events encountered beyond the learning situation could be more readily accessed than apparently irrelevant information. It seems reasonable that in order for students to be able to recall information about science, they must be able to see its relevance to their lives.

Information processing theories have suggested that knowledge is organized into structures and categories of information with links between related concepts. Schema have been described as one model defining the sense making process. If new information fits into existing schemata, then this process of assimilation can provide the learner with an efficient mechanism for making sense of data. Posner et al. (1982) have argued that one of the reasons students can have trouble accepting scientific explanations is that often scientific understandings are radically different from common sense understandings about events. Assimilation of information into existing schemata may not be appropriate for all learning in science education. In the next subsection, some ideas about how students can accommodate inconsistent information are discussed.

Accommodation of Inconsistent Information

In the above discussion, the term assimilation has been synonymous with the process of developing schemata in which new information is added to existing conceptual structures. Sometimes, in bridging the gap between everyday understanding and scientific understanding, conceptual structures must be replaced or reorganized (Posner et al., 1982). The term "accommodation" is used to define the radical restructuring process. A common concern in science education research relates to the resistance of students' ideas to conceptual restructuring. Another problem relates to the acknowledgement that restructuring can as easily move a students' understanding of events away from a scientific view as toward it (Osborne et al., 1983; Champagne & Klopfer, 1984).

Champagne and Klopfer (1984) suggested that information can be poorly organized both within schemata and between schemata. Students can demonstrate a confused understanding about events. Champagne and Klopfer have termed such organizations of knowledge as "naive schemata." Carey (1986) argued that new schemata and new links between schemata can be built as new information provides links between nodes of knowledge. Champagne and Klopfer (1984) pointed out that often students' naive schemata relating to scientific principles remain unchallenged by contradictory experiences and therefore remain resistant to creating links between schemata. Driver and Bell (1986) noted that, even if attempts are made to challenge students' naive understandings, events can be interpreted by students in various ways.

One promising route to increasing students' critical assessment of their own understanding seems to be to encourage reflection on consistencies and inconsistencies within their own thinking. Children are often influenced by the views of their peers more than by an instructor (Osborne et al., 1983). The value of sharing ideas with others as part of children's sense making experiences is discussed in the next section of the literature review.

Reflecting on Information to Shape Understanding

Another part of the complex mixture of ingredients for constructing sense and re-constructing to make more sense seems to be a process of talking about ideas with others and reflecting on one's knowledge. Several researchers, in particular Schön (1988), have studied ways that experts can reflect on their experiences and how they can use the experience to gradually guide a novice toward a greater level of expertise.

This section of the literature review examines three features of Schön's (1988) work which are relevant to the current thesis--that talking about one's understanding leads to vulnerability and confusion, that developing a new understanding requires a transformation of knowledge, and that telling stories can act as a metaphor for transforming knowledge. Discussion of Schön's work leads into an examination of the work of Bruner and others who are concerned primarily about constructive learning processes for children.

Three points from Schön's (1988) work seem to be particularly relevant to discussion within the current thesis. First, in reflecting on one's work, there is vulnerability and confusion. Reflection causes one to reassess the accepted solutions to problems and to question inconsistencies. Duckworth (1986) pointed to two reasons people may resist reflecting on their beliefs and understandings. First, it is difficult to admit that one does not understand. Second, adults often assume that misunderstanding represents a personal weakness. It takes courage to admit not knowing. Fortunately, children can use play as a passage to understanding. The role of play and language in learning are discussed later in the section.

Schön's (1988) second point relevant to the current study is his notion that in order to become an expert, knowledge cannot simply be transferred from expert to novice but must be transformed. He suggested that "reflective transformation" involves a "process of metaphor, carrying a familiar experience over to a new context, transforming in that process both the experience and the new situation" (Schön, 1988, p.25). The ideas seem to be consistent with information processing theories, suggesting that knowledge must be reconstructed and new links made between schemata in order to create new problem solutions.

In a series of lecture notes presented at Queen's University, Schön (1984) argued that students often have trouble following a teacher's instructions because they have not had enough practical experience to make sense of what the teacher wants. This need to have touched and experienced before and while receiving instruction seems to be part of the process of creating a metaphor that an individual can use to "reflectively transform" information. Schön's claim supports Bruner's (1983) view that play is essential to the sense making process. The concept of reflectively transforming information through the creation of metaphors also supports Vygotsky's (1978) claim that language is the main tool children use to internalize their understanding about experiences. The role of language and play in children's sense making are discussed more thoroughly below.

A third point raised by Schön (1988) is the notion that reflections on observations are often embodied in a story. Storytelling, he suggested, provides a metaphor for transforming knowledge in new situations. Storytelling, along with play, seem to be important tools used by children in the process of constructing knowledge about a situation. Bruner's (1983, 1986) ideas about the role of play and language in learning are discussed below.

Reflections on Children's Use of Language and Play

Bruner (1986) began his thoughts about the role of language in the development of ideas with reference to Vygotsky's (1978) view that language is a way of sorting out one's thoughts, while thoughts provide a mode of organizing perception and action. Bruner (1976) argued that in order for a learner to acquire language and skills there must be a support system within the child's learning environment. He suggested that Vygotsky's "Zone of Proximal Development" (ZPD) could explain the process through which a more competent person could assist a less competent one to achieve new understandings.

Bruner (1976) illustrated how a mother can gradually assist a child to learn new elements of language through a blend of two processes. She can provide the child with the language he cannot use at a particular stage of development and she can work with the child, allowing him to do things he could not do without her. Once the child has mastered one skill, the child's ZPD is shifted and the mother's expectations are increased. The learner develops as he responds to challenges set at increasing levels of mastery.

Another way of viewing the interaction between tutor and pupil is a model of scaffolding. Greenfield (1984) defined five characteristics of the scaffold model. It provides support, it functions as a tool, it extends the range of the worker, it allows the worker to accomplish a task that would not otherwise be possible and it is used selectively to aid the worker when needed. Models explaining how the less competent become more competent through social supports emphasized the fact that learning is influenced by the culture, language and beliefs of the learner's society.

Whether children are learning language skills or whether they are learning about a wetland, there will be an interaction between their existing knowledge and their new sense experiences. Vygotsky (1978) suggested that children's speech and language are the main tools for internalizing their sensual experiences. Children's use of language in making sense of experiences is extremely important in shaping their knowledge. Bruner (1976) stated that "the role of language...implies a view...about the symbolic environment and how one is presumed to operate within it" (p.142).

Symbolism in language can be expressed in a number of ways. Bruner (1983) discussed the interaction of play, language and thought as a means of growing. Sutton (1980) argued that the language symbols used in science are often thought of as fixed and determined. He suggested that science students should be encouraged to see meaning as something which has to grow, encouraging metaphorical connections between concepts. The idea relates well to schema theories and the current theoretical view that knowledge is constructed by creating new links between thoughts but contradicts Hawkin and Pea's (1987) assertion that scientific language is distinguishable by its lack of metaphors. In the next several paragraphs, the role of linguistic symbols and of play in the development of knowledge are discussed. The discussion begins with reference to Schön's (1988) argument that stories carry ideas across barriers and provides a definition for "metaphor." Language as a cultural barrier is then discussed, followed by a discussion of how metaphors can be applied to science education as a tool for encouraging students to accept scientific principles.

Within the analysis and discussion chapters of the current thesis, students' metaphors are often explored as linguistic symbols explaining the children's internalized understandings of concepts. Metaphors are often found in the student's stories and talk surrounding play. As Schön (1988) has noted, the term "metaphor" derives from a Greek term, "metapherein," meaning to carry across. Beck (1978) argued that a metaphor illuminates parallel elements of concrete images in order to formulate more abstract relationships between relevant sets of characteristics. Furthermore, a metaphor is a means through which sensory experiences can be organized to fit verbal codes. Since verbal codes are limited by language, metaphorical images must also be tied to cultural uses of language (Lakoff & Johnson, 1980).

The role of language in defining cultural differences has been outlined by Pascale and Athos (1981) as a consideration for American businesses hoping to compete in Japanese markets. The Japanese language allows for the omission of verbs from sentences, which produces a great deal more ambiguity within statements than does the English language. The Japanese are trained to pay attention to the space around them, recognizing that the hollows left inside jars, or the holes in walls for windows and doors, help us by what is not there, to use what is there (Pascale & Athos, 1981, pp.142-143). It is relatively easy to recognize the linguistic cultural differences between Japan and North America. It may not be quite so easy to define the cultural differences between everyday perceptions and scientific perceptions of events.

The cultural gap between common sense and scientific explanations for events has been discussed above. Bridges between the cultures have been considered, such as learning to recognize and overcome critical barriers (Hawkins, 1978). Lakoff and Johnson (1980) suggested that the acceptability of scientific theories rests in part on how well the metaphors used to define the theory fit the students' own experiences. Students' resistance to accepting scientific principles may in part be due to the effects of everyday culture on their language development.

Snively (1987) has demonstrated that using children's everyday metaphors to describe features of the ocean environment can increase students' interest in and understanding of ecological relationships. Snively (1987) suggested that using metaphors in instruction can lead to whole systems of related concepts. Students in her study used metaphors to construct meaning. One result, Snively suggested, was that students can learn to recognize that scientific meanings are flexible. Snively included in her paper part of a transcript in which students in a grade six classroom were using a spaceship metaphor to discuss the life supports of a sea urchin. The students' interest was maintained by the novel metaphor, and there was an element of play in their language.

Play is an extremely important element in the lives of children. Bruner (1983) argued that play serves a range of roles in students' construction of knowledge. Since it is considered to be fun, the consequences of error are lower in play than in tasks. Children can change the rules of their play as it progresses. Larkin and Rainard (1984) suggested that a good problem solving model sets rules for testing parts of a problem. If new components are added to the problem, new rules may be needed. Similarly, in play, children can add new rules if they are required. It would seem that play provides an opportunity to test problem solving strategies.

Play is an activity most often done with other people. There is, therefore, an interaction between different perceptions and understandings of the same situation. Because play is non-threatening, it can be used as a place to test out concepts that are, in fact, beyond the child's current abilities. Children can test the limits of their own development through play. One last and rather interesting observation made by Bruner (1983) about play was that when an adult involved a group of children in a high level intellectual activity, their play became richer and more elaborated than when children played only on their own. Elements of play found in the students' talk during the wetland study are discussed within the analysis chapters and in chapter 6.

Qualitative Methodology

The final section of the literature review considers my choice of a qualitative research study. Some considerations to be taken while doing a qualitative study are discussed. The section ends with discussion of some influences on the design of the curriculum for the wetland unit.

The decision to conduct a qualitative research study as opposed to a quantitative study was based on a number of factors. The most important considerations were related to the perspective I wanted to use to examine the problem. Since I wanted to be involved in a short term teaching unit and to examine students' understanding within the context of the unit, it was clearly a contextually based study.

Kilbourn (1980b) discussed characteristics of an ethnographic paradigm for research in classrooms. In an ethnographic study, the context in which events take place is important, including contextual features such as intentions and motivations of teachers and students. There is not a rigid distinction between the observer and the observed. In the current study, I acted as a participant-observer. My greatest personal goal in conducting the research and in later analyzing and discussing the data was to construct understanding about the dynamics of a teaching unit in a way I had not been able to achieve within my regular teaching. The decision to conduct a qualitative study was clear.

Experts in the field of qualitative research (Bogdan & Biklen, 1982; Miles & Huberman, 1984; Mathison, 1988) agree that extensive field notes are essential to the success of qualitative research. Bogdan and Biklen (1982) recommended keeping notes of observations to provide portraits of the subjects, description of the setting and of the activities observed and notes on the observer's own behaviour. They also recommended writing reflections on the analysis, on the method, on conflicts encountered during the study, and on the observer's frame of mind. The recommendations may seem trivial to a more experienced researcher, but they are worth mentioning here because they guided my notekeeping. My success in collecting data as a participant-observer will be discussed within chapter 6.

Miles and Huberman (1984) argued that qualitative researchers have a set of assumptions, decision rules and criteria for assessing data but that these remain mostly implicit. The researcher's decisions about how to reduce the data and to display it can present a different impression of the observed situation.

How can different images be brought together to construct a plausible explanation about the phenomena being studied? Mathison (1988) suggested that triangulation can provide evidence to help the researcher make sense out of a confusing web of information. Triangulation can be of three types. For data triangulation, data can be collected over a period of time, for investigator triangulation, several observers can collect data about the same situation and for methodological triangulation, multiple methods can be used for collecting data.

One purpose for using triangulation in qualitative research is to increase the internal validity of the study.

Internal validity refers to the extent to which observations are authentic representations of some reality (Goetz & LeCompte, 1984). External validity refers to how well the representations can be compared across groups. Due to their nature, qualitative research studies often have limited external validity.

Influences on the Design of the Study

Two types of influences on the current thesis are defined in this part. The first are influences on my ideas about how to present curriculum during the unit. The second are science education research studies which influenced the design of the thesis.

During the summer of 1989 David Hawkins presented a summer course at Queen's on science education. I attended several of the lectures and was struck by the number of opportunities he found to have us estimate the size and scale of things like soap bubbles, and leaves on trees. I felt that these problems about things I had always taken for granted could provide fascinating stimuli for the students I was working with at the time on the wetland study. I presented the students with problems similar to the ones that David Hawkins was presenting to his class but centred on the environment the students were studying.

There is no good rationale for having added the problems. I acted as I would in any teaching situation with students. When a great idea comes to me, I want to test it out for myself as quickly as I can. I had a group of students to work with in July in an appropriate setting. Within the culture of teachers, new ideas from workshops are often put into practice as quickly after having experienced them as possible. There has not always been time to reflect on the material before presenting it to others but students' responses to materials can be considered for many teachers an essential step in the process of assimilating new information.

Several research studies influenced the design of the thesis. There are very few qualitative studies which have observed students and recorded their talk throughout a unit of study. Aguirre and Kuhn (1987) observed students throughout a one month study on nuclear energy but their primary concern was to analyze the teaching characteristics that can improve student learning. Bloom (in press) interviewed children as they examined earthworms. He used the unfamiliar situation to explore how children construct meaning but interviewed each student only once. The current study uses the relatively unfamiliar situation of exploring a wetland to inquire how students make sense of unfamiliar concepts throughout an entire unit of study.

A few studies in science education research have used a range of methods to collect data but many have focussed on just one method. Aguirre and Kuhn (1987) were able to assess the success of students' learning by incorporating a number of data collecting methods within the observed unit of study. Bloom (1990) used several methods to examine how students construct meaning. He described the value of context maps and of visual metaphors as methods for revealing students' understanding about the world. In the current study, neither of these methods was used but Bloom's (1990) analysis of how students construct knowledge was influential in my considerations of how to organize the analysis in the current study.

Two studies which used one method to collect data about students were influential in the design of the wetland study. Snively (1983) used a metaphor interview to determine students' orientations towards the seashore. She asked students to complete statements such as "the lake is like a..." with a choice of five metaphors. Students' explanations for the choice of metaphor were analyzed to determine how the students felt about the seashore and what they understood about it. Snively (1983) used the metaphor interviews to design a unit of study about the seashore incorporating metaphors selected by the students as a way of making strange concepts more familiar to the students., I used the metaphor interview technique near the end of the wetland unit to see what would be revealed by the students when they were asked to respond to ideas that changed the lake setting from something that had become familiar to them to something strange.

Gilbert, Watts and Osborne (1985) used a different type of interview technique from Snively (1983). Using an Interview-About-Instances (described above), students were encouraged to explain their answers to questions about physical principles. Transcripts from Interviews-About-Instances (IAI) were used to determine how students' use of certain words affected their concepts about physical phenomena (Gilbert et al., 1982).

Gilbert et al.'s (1985) interview technique was not used directly in the current study because it was felt that students' ideas about concepts being examined in an environmental study could not be appropriately reduced to questions answerable with "yes" or "no." The IAI method did influence one part of the design of the current study. Within the initial interview and the final interview, students were shown a series of pictures about wetlands and were asked to answer simple questions about the pictures to determine what they understood about wetlands at the start of the unit and to make comparisons at the end of the unit.

The literature review has outlined several theoretical perspectives that are considered to be important in developing a framework for the current thesis. The next chapter describes the setting for the study, the selection of students, the curriculum and the data collecting methods.

CHAPTER 3

DEFINING THE DATA COLLECTION AND ANALYSIS PROCEDURES

Outline of the Chapter

This chapter consists of four sections. The first section describes the setting, the selection of the students and an outline of the daily program provided by me as the instructor and researcher. The second section describes all but one type of data collected during the study. Since individual interviews provided a large amount of the data used for the analysis, they have been discussed separately in the third section of the chapter. The fourth section describes how the analytical framework for the thesis developed from preliminary examination of the data. Characteristics of each student are described at the beginning of the next chapter, the first chapter of the data analysis.

The most valuable data collected during the study is on audio tapes. Most of the students' comments recorded during the unit have been transcribed. Three tape recorders were used for recording large and small group sessions with the students. During the two week unit I provided the students with an increasing number of ideas about how to examine water samples but the main task--examining samples of water taken from a wetland area--remained the same. In addition to the group sessions, each student was interviewed three times as part of the study. The interviews were all recorded. Other methods used for collecting data included drawings and handouts created by the instructor.

Instructional Setting

The city in which the study was conducted has a summer camp program situated on an island within the city limits. Permission to involve students from the summer camp program was obtained from the camp administrator based on approval of a research summary proposal (Appendix A). The island used for the camp program lies near the mouth of a wide river leading into Lake Ontario. The island is cut off from the mainland by a narrow band of stagnant water. Around the island are a variety of marshy and swampy shores. The main campsite was near a particularly accessible area of marshy water, protected from the rougher water of the river by a bay filled with reeds and lily pads. It became the site for sampling throughout the two week camp.

Within the first few days the students were able to find the last dragonfly nymphs of late spring and to collect young catfish. By the end of the second week of camp hot July temperatures had increased the coliform count in the water to a level causing beach closure.

The camp was open to children from across the city. They came from areas with many professional families and from areas with single parent, subsidized housing. The camp was organized into several two week sessions throughout the summer. The first session was the one used for the wetland study.

The camp held a canoeing programme that allowed several of the students to observe the protected bay's waters from a different perspective. The researcher made one canoe trip with three of the students. Several students referred to their observations made while canoeing during interviews with me.

One camp activity in particular had a direct effect on the quality of student data produced. There was an overnight stay on the Wednesday of the second week. The students were excited and distracted on the Wednesday of the camp-out and exhausted on the Thursday following it. Wednesday was reserved as an individual interview day and Thursday was taken up by active games for half the time and only a twenty minute sampling time to accommodate the students' lack of ability to concentrate. The students met as a group with the researcher for thirty to forty five minutes for nine days during the two week camp.

Selection of Students

The students in the wetland study were all between the ages of ten and eleven. An invitation to participate in the study was originally given to all camp participants between the ages of ten and twelve. A letter summarizing the purpose of the study and asking for permission was sent to all families registering their children in the ten to twelve year old group (Appendix B). All children for whom a signed permission form was returned were invited to be in the study.

On the first day of camp the counsellors broke the ten to twelve year old group into two sections, divided by age. The children signed up for the wetland study were therefore divided between the two groups. Two of the children who were originally signed up for the study did not want to participate. Both of these children were in the section containing the older children. A ten year old girl not previously enrolled asked to be allowed to participate in the study. Nine children were interviewed individually on the first day. Five of these were from the younger group, four from the older group.

By the time the students met on the second day, a lot of group building had already occurred. All but one of the children from the older group decided on the second day that they would rather not be in the study. The remaining group of six therefore consisted of five children from the younger group and one, Diane, from the older group. Once the group was established it consisted of three girls and three boys. The girls have been given pseudonyms beginning with the letter "D", while the boys have been given names beginning with "S". The students are referred to throughout the analysis as Stan, Scott, Steve, Diane, Denise and Dana.

Effects of the Teacher as Researcher

The group dynamics were affected not only by the students but also by me as the teacher and researcher. How they behaved and what they revealed depended to a great extent on what they thought I wanted to hear as a researcher and how comfortable they felt with my style as an instructor.

As an instructor, I wanted to provide a casual setting that would not be equated with a classroom unit of study. This seemed to be particularly important because the camp provided fast paced games in which the children enjoyed participating. I felt for the first few days that my study had to be equally entertaining to maintain the interest of the children. By the fourth day the students in the group were willing to concentrate longer and more intensely on examining water samples.

I had available nature magazines and an assortment of illustrated texts about the environment but I specifically focussed the students' attention on illustrations from only one nature magazine (Ontario Federation of Naturalists, 1979). Although several students quickly flipped through the texts I had provided, they did not refer to them as a guide during their observations of samples.

Several types of magnifiers and sample collecting tools such as eye droppers, basters, petri dishes, insect nets, jars and buckets were provided during the session. The students seemed to enjoy experimenting with the equipment. Each day a new activity or a new piece of equipment was added. The sessions, which were all 30 to 45 minutes long, were set up to begin with a five minute regrouping to discuss what had happened the previous day, to present an overview of the day's events and to introduce any new activities. The group meeting was often followed by a game. The remaining 20 to 30 minutes was spent collecting, observing and talking about water samples in pairs or as a whole group. I arbitrarily set the pairs each day because I wanted to see how certain pairs of students would interact. Sometimes they worked together happily. Sometimes the tapes recorded 30 minutes of near silence.

Features of the Curriculum

Incorporated into the daily activities were a number of experiments and games. Each of these activities was included to stimulate students' thinking about several broad issues related to the wetland environment. An instructional activity which presents students with concepts related to the unit of study but introducing concepts at a level beyond which they are presently able to grasp has been found to encourage students to think at a higher level (Joyce & Weil, 1986). "Advance organizer" is the term used to define these teaching tools (Ausubel, Novak & Hanesian, 1978). The experiments and games were used as instructional tools rather than as data collecting tools. They are not specifically dealt with in the analysis although mention of some of the games and experiments is encountered in the students' talk.

The greatest influences on the design of the curriculum were my own notes from previous teaching experiences and notes from lectures with David Hawkins at Queen's University in July, 1989. David Hawkins discussed at length the repercussions to all areas of science education when students cannot grasp fundamental principles of size and shape. In a wetland environment, students' inability to grasp concepts of size and shape can be reflected, for example, in their lack of concern about how organisms can survive in an aqueous environment. The games and experiments were planned to encourage students to think abstractly about the wetland as they examined concrete information and samples.

Three types of games were played during the unit. The one that was used most often and was most popular with the students was a wetland version of the game "Survival." Students were selected to play either plants, animals, microbes, man or pollution. The students were given several pieces of paper to represent lives, with the number of lives roughly representative of the number of each type of organism existing in the wetland environment. If they were caught, they had to give up a life. If they were caught by a microbe, they exchanged lives, representing the principle of symbiosis. Pollution was released late in the game but was given power to destroy everything it touched.

Out of the Survival game derived "Wetland Hide and Seek." One of the students constantly eluded the others in the Survival game. He offered to share with them the secrets of his success--staying low, camouflaging himself by careful hiding, and leaving shelter only after he had ensured there were no predators. After playing "Wetland Hide and Seek," the students' performance in "Survival" improved.

The third game emphasized a concept related to size and shape. On the seventh day of the unit, pairs of students were handed scissors and a letter sized sheet of paper. They were asked to create a piece of paper that could make a circle encompassing two trees. The purpose of the game was to introduce the students to the concept that careful design can increase surface area without increasing volume.

Three experiments were introduced to the students during the wetland unit. The first demonstrated different properties of air bubbles in a full and a half full jar, to illustrate how air becomes distributed in water. The second experiment gave students an opportunity to consider the population density in the marshy bay. During two individual interviews the students were invited to count the number of organisms they could see in a 10mL water sample and to then estimate the number of organisms in a 1L sample, which was the amount of water usually collected in the sampling buckets. They were then asked to extrapolate, guessing the number of organisms that could live in the sheltered bay from which they collected samples.

The third experiment was taken directly from a lecture with David Hawkins. As a way of observing that surface area can increase without changing volume, one drop of green food dye was added to a 1L jar of still water. Several students wanted to repeat the experiment, or to try modifications of it. Within the transcripts are several references to the experiment but they are not discussed in the analysis.

Types of Data Collected

One purpose of the study was to use a variety of data collecting techniques in order to provide information about which strategies were most effective for generating data during a short, instructor led research study. Methods used for collecting data consisted of drawings, completion of teacher created handouts, field notes, audio tapes of all water sampling sessions, three tape recorded individual interviews with each student and transcripts.

Several methods were used during the interviews to obtain information from the students. First, students were shown pictures of wetlands and wetland species and asked to answer questions about the pictures. The pictures were shown in the first and in the third interviews. Reproductions of the pictures are included in Appendix C. In the second interview, the students were asked to complete metaphorical statements such as "the lake is like a..." from a selection of five words offered to complete each statement (Appendix D). In all three interviews the students were asked to talk about their understanding of the wetland area by examining and talking about freshly collected and bottled water samples. From the second to the sixth days, students were encouraged to collect samples for bottling and observing later.

All of the data collecting techniques are described below. Information about the individual interviews is discussed in the third section of the chapter. The value of each data collecting method as a tool for eliciting students' understanding will be discussed in chapter 6, providing a basis for assessing the value of the data provided by each method.

Drawings

A preliminary wetlands study involving six grade five students indicated that students' ideas about a wetland can be succinctly disclosed by having them depict life in a wetland through art. In the preliminary study, the students were given 20 minutes to create a three colour drawing in a quiet classroom. The preliminary study was conducted under different conditions from the current study. It will not be discussed within the current study.

During the summer the students had to work outside on windy days using large hard covered books as their desks. In addition, the marshy bay lay behind them as they worked and they were anxious to finish their drawings so that they could get on with sampling the water.

The students were asked to make six drawings throughout the wetland unit. On the first and on the ninth day the students were asked to explain life in a wetland using a combination of images and words. They were asked once more to depict life in a wetland at the beginning of the follow-up interview 4 weeks after the session was completed. The other three drawings could be of any organism they had observed on days 3, 6 and 9.

Teacher Created Handouts

In order to give the students an opportunity to express their ideas on paper, I created two handouts for them. The first was presented to them on the second day of the study while the other one was given on the third day. Since the students did not appear to be interested in writing and paid little attention to the handouts they were not used after the third day.

The first handout (Appendix E) asked students to provide information about their personal interests. They were also given space to describe one new thing they had learned about the camp environment and to write their ideas about the bubble experiment described above.

The second handout (Appendix F) asked students to draw a specimen after they had observed it carefully. They were asked to focus on its movement and on its gross anatomy. After drawing it, they were asked to list three words describing the specimen. All of the students drew a sample but none wrote descriptive words so on subsequent days, students were given blank paper to complete their drawings.

Field Notes

Prior to beginning the unit, I had created an ambitious curriculum outlining each day's activities and the data collecting methods I intended to use (Appendix G). My field notes were used as both a teacher's diary and as a researcher's diary in the sense that they contained notes both about revisions of the curriculum and notes about the students as subjects. One day's notes are included as Appendix H to illustrate the types of field notes collected during the study.

On the fourth day of the session, a graduate student offered to take field notes in order to practice her skills as an observer for a course on qualitative research in education. Her notes are included in Appendix I, as a contrast and comparison to my notes taken as a participant-observer on the same day (Appendix H). The second observer provided an element of investigator triangulation to the data. Similarities and differences between the paricipant-observer and the observer's notes are discussed in chapter 6. The discussion examines whether or not field notes taken from a different perspective increased the internal validity of the study.

Tape Recordings

Tape recorded sessions were felt to be an essential data collecting technique. First of all, the data provided by tape recordings cannot be disputed since they record accurately what has been said. Second, tape recording allows the researcher to reflect on what has been said once all of the data has been collected. Third, tapes can be transcribed, allowing the researcher to analyze students' talk.

Fresh batteries were used in all of the tape recorders each day to avoid technical problems. It was expected that the students would feel uncomfortable and self-conscious about being recorded for the first few days. The tape recorders were used as frequently as possible to allow the students to become comfortable with their presence. All individual sessions with students were also recorded. Procedures used during the interviews are discussed below.

Individual Interviews

Several strategies were used during the interviews to draw information from the students. Each child had three individual interviews lasting from ten minutes to one hour. The length of the interview depended both on the number of questions being asked by the researcher and on the student's willingness to converse. The interviews tended to get longer as the students became more familiar with the researcher and were more willing to talk about their ideas and their observations. The first two interviews were conducted on the first and on the seventh days of the nine-day camp session. Each child was interviewed for a third time 4 weeks after the session had been completed. Two of the students were at the campsite for an extra session and were interviewed there. The remaining four students were interviewed at their homes.

As part of one or more interviews, students were asked to answer questions relating to pictures about wetlands, they were asked to orally complete metaphorical statements such as "a lake is like a..." and they were asked a number of questions about freshly collected and bottled samples to keep them talking about water samples they were examining. The questions changed with each interview. They were used to encourage the students to talk more about their thoughts as they played with the water samples. Each strategy will be discussed separately below.

Questions based on Pictures about Wetlands

After being asked to depict life in a wetland on the first day of the wetland unit, the students were asked to look at several sets of pictures and to answer questions about each. All of the photographs were shown from one magazine (Ontario Federation of Naturalists, 1979). The first set of pictures were presented as a collage, with shots of a blue heron, a frog and marsh marigolds set to the side of a sunset photograph of a marsh. The students were asked to comment on how the four pictures could be related to one another. Students were shown the collage of photographs again at the beginning of the third interview.

The second set of pictures were arranged to symbolize the caption above them, "Battle for Wetlands." In the centre of the photograph was a judge's gavel, separating a toy bulldozer from a robin's nest on a branch. The title of the photograph was hidden from the students while they were asked to comment on what they thought the image meant. The question was asked to determine the students' awareness of environmental issues. It was felt that knowing what the students understood about the loss of wetlands might influence their understanding about wetlands or their approach to the wetland study. Students were only shown the "Battle for Wetlands" photograph during the first interview.

The third set of photographs was of four water organisms. Students were asked questions about the pictures, depicting in turn a fishing spider, a fairy shrimp, a backswimmer and a water tiger. Fairy shrimp were present in the bay at the time of the initial interview. Although there were other reasons for asking questions about the four photographs, the main purpose was to ask the students if they thought that fairy shrimp could live in the bay. I wanted to know if the students would be surprised to discover that shrimp can live in fresh water.

There were other purposes for asking the questions. The water tiger and the backswimmer were both hanging just beneath the water surface. I wanted to know if any of the students had observed water organisms hanging from the surface of water. If they had, it would indicate first that they had spent some time previously examining water organisms and second that they were willing to see that tiny organisms can cling to the surface of water without breaking it. Such an understanding would contradict most children's experience with water, that it is a substance incapable of supporting weight.

The students were asked if they thought the fishing spider could catch fish. The reason for the question was to determine if the students would agree that a tiny organism was likely to catch and eat a much larger one, and how the students would make sense of the spider's name. There were clues to its name in the photograph. Its long probiscus was silhouetted against a reed. During the third interview the students were again shown the photographs of the water organisms, but at that point were only asked to comment on whether or not they had seen any of them.

Creating a Metaphor about the Lake

Since the wetland study was intended to be a study by a teacher of a group of students in as natural a learning setting as possible, it was felt that enormous amounts of data could be collected and be exceedingly difficult to analyze. Snively (1983) had developed a series of questions grouped to create a "metaphor interview" to ascertain students' beliefs about and orientations toward the sea. By giving grade six students a choice of metaphors to describe the sea and its attributes, Snively suggested that it was possible to interpret children's understanding about the ocean. It was felt that a modified, shortened version of Snively's (1983) metaphor interview might provide clues in the current study to students' understandings about the lake to which the marshy bay was attached. During the second interview, ten questions were asked of each student using the modified metaphor interview (Appendix D).

Each student was asked the question "a lake is like a..." four times. Each time they were given a choice of five different words to complete the sentence. After they had made each choice they were asked to explain the selection. The next three questions asked the students to compare the sun, lake water and mud each to one of five possible metaphors. All possible choices are listed in Appendix D. The last three questions asked the students to complete the phrase "I am to the lake as..." One set of possible statements to complete the sentence was "I am to the lake as....the lock is to a necklace; or a bead is to a necklace; or string is to a necklace." Students' talk about their choices was recorded and examined as part of the interview transcript.

Questions about Water Samples

Since the main task presented to the students during the wetland unit was to examine water samples, a large part of each interview was devoted to examination and discussion about samples. In order to encourage student talk about the samples, a number of questions were presented to them during each interview.

During the initial interview, students were simply asked to look at a sample of water collected in a shallow bucket. Water sampling tools were always available to the students, including buckets, basters, jars, sampling dishes and a magnifying glass. After they had had several opportunities to examine water samples and to collect and bottle samples, students were asked on the seventh day of the session to examine samples during a second individual interview.

Three main questions were asked of the students as they were examining the water samples during the second interview. First, they were asked to comment on anything they found in the water sample that was new to them or seemed unusual. A number of questions about their observations arose from student comments. The questions related to topics such as how the child thought tiny water organisms might eat, how they could move, how long they might live and how they could survive in the well populated bay. Second, each student was asked to examine one bottled sample and to comment on how it was changing and what might be living in the specimen jar. The final question asked of all the students required them to extrapolate from the sample they were examining by estimating the number of organisms collected in a small sampling jar and from that to guess the number of organisms that they thought could be living in the marshy bay.

Throughout the unit the students talked about "pollution" in the water. I wanted to know more about what the students understood about water pollution. During the final interview when they were examining a water sample I asked them first to comment on anything that was new or unusual to them in the sample, then asked them whether they thought there was pollution in the water they were sampling. I asked them to talk about pollution in the lake. Again, questions about the samples stemmed from the students' talk about the samples. They were all asked to comment again on bottled samples and to speculate on the number of organisms that could live in the marshy bay that they had been observing. The three main questions were the same in the second and third interviews in order to allow comparisons between the students' answers.

In total, five methods--drawings, handouts, field notes, tapes and transcriptions from tapes, and individual interviews--were used to collect data during the wetland study. Several patterns of students' understanding emerged during the session. These are described and discussed in chapter 4, which analyzes students' understandings about wetlands based on categories of ideas. How the analysis developed is described below.

Development of the Analysis

Prior to collecting the data, several suggestions about how to analyze it had been discussed with my supervisor, members of my thesis committee and other interested graduate students. Only after the tape recordings had been transcribed did it become clear that there were patterns of thoughts emerging from the data that could be used to discuss students' ideas about the wetland.

In order to clarify what patterns were emerging, I began by linking students' ideas that seemed to express similar ideas, then I began listing several possible categories of ideas. As I shared these ideas with others, the framework for the analysis became progressively clearer. Four main types of ideas seemed to be expressed--strongly held ideas, ideas changed readily by observation, developing ideas, and confusing or contradictory ideas. These categories of ideas illustrate features of schema theory.

Schema theory suggests that students can have clear links between pieces of knowledge held mentally in schemata (Champagne & Klopfer, 1984; Carey, 1986). Several researchers (Vygotsky, 1978; Ausubel, Novak & Hanesian, 1978; Osborne & Wittrock, 1983) have suggested that students draw on their existing knowledge and on language to help them make sense of new information. If students' ideas are not clearly developed or linked to other ideas in a stable network of knowledge, then it may be difficult for them to recall pertinent knowledge for sorting new thoughts (Champagne & Klopfer, 1984).

As the data analysis was emerging for the current study, it became clear that some ideas were agreed upon by all the students, such as that there was pollution in the water. These were termed "strongly held ideas." The category of "developing ideas" illustrates that there are levels of knowing about the wetland environment. This category reveals that students with greater experience related to a situation can recall knowledge and make sense of new information more readily than can students with less related experience. "Ideas changed readily by observation" refers to a few ideas that changed when students could see that their ideas were not supported by evidence in the wetland environment. The final category, termed "contradictory and confusing ideas" provides some of the most interesting evidence to suggest that students do not always link knowledge in ways that are expected by an instructor. The categories are discussed and developed with examples from the transcripts, forming the framework for chapter 4.

A second level of analysis emerged from work on categorizing students' ideas. As the students worked, it became clear that they played with materials a lot and that as they talked about their ideas, they were working out their understanding. Their understandings about the wetland environment differed from one another. Dana and Stan provided the greatest contrast between students in the group. The contrast, based on an examination of the transcripts, is developed as an examination of two different problem solving approaches. Transcripts from Dana's talk were written on a large sheet of paper to help me make sense of what she was saying. I created a code to help me see how she was using language to help her make sense of her thoughts and how she was recalling ideas from one session to the next. The second level of analysis emerged as a comparison of how one student used the features of scientific investigation--hypothesizing, comparing, observing--while another student used metaphors and stories to make sense of the environment. The second level of the analysis creates the framework for chapter 5.

Chapter 6 summarizes the study, discusses the findings and assesses the value of each of the data collecting methods as a means of encouraging students to reveal their understanding about the wetland environment.

CHAPTER 4

PATTERNS OF STUDENTS' IDEAS

Factors Affecting Students' Understanding

The first level of the analysis outlines four categories of ideas based on students' talk about concepts related to wetlands. "Strongly held ideas" refers to ideas generally agreed upon by all of the students. "Developing ideas" refers to concepts that seemed to be related to the students' previous experience exploring wetlands. "Ideas altered by observation" refers to ideas that seemed to change readily when evidence challenged students' beliefs. A fourth category of ideas examines students' contradictory or confusing statements relating to wetlands.

The four categories of ideas are used to explore what factors affect students' understanding. They are discussed in chapter 4 after an introduction to each students' character. The students are introduced individually but the introductions are organized to highlight pairs of students. Three pairs seemed to develop within the group. The students did not begin to be thought of as distinct pairs by me, however, until a plan for the analysis had developed after completion of the wetland unit. Scott and Stan had the greatest amount of prior experience exploring marshes and they often had ideas about the wetland not expressed by the other students. Diane and Steve both seemed to have a lot of general knowledge that they were able to apply to the unfamiliar experience of exploring a wetland. Dana and Denise seemed to have less general knowledge than Diane or Steve that they were able to apply to their explorations of a wetland.

Throughout the analysis, there are clues in the students' talk about how they made sense of unfamiliar material and how they solved problems. This information will not be dealt with in the current chapter but will form the basis for the second chapter of the analysis, chapter 5. Dana revealed a great deal of information to me during individual interviews. Dana's revelations about her understanding of the wetland were particularly interesting because at one level they often seemed to be confusing and often contradictory while at another level, there seemed to be a logical sense making process. In chapter 5, Dana's sense making activities will be discussed and compared with Stan's responses. Comparisons and contrasts between Stan and Dana suggest interesting similarities and differences in the approaches to problem solving used by two students examining the same environment from different perspectives.

Characteristics of the Students

The students are introduced individually but their profiles have been arranged in pairs. Stan and Scott are introduced first, then Diane and Steve, ending with Denise and Dana.

Stan clearly had previous knowledge about wetlands and had a vocabulary appropriate for discussing his knowledge. He was seen by the other students to be an invaluable resource. He offered guidance to Scott and also to Steve. When he was working with either of the other boys Stan revealed his knowledge about wetlands very clearly. He was never partnered with Denise or Diane, but when he worked with Dana, neither one spoke for 20 minutes. Stan did not seem to enjoy the individual interviews and spoke very little during them.

Scott was a quiet boy who had a great deal of practical experience in observing water samples and water organisms based on his explorations of marshy waters near his family's cottage. He spoke much less than Stan and did not seem to have developed a vocabulary to describe his observations. He enjoyed collecting samples and spent much of his time finding interesting specimens. He was not as enthusiastic about examining the samples he had collected. His answers to questions were often terse but clear. Scott seemed to be willing to take orders from the other boys in the group, to collect samples for them, or to engage in tasks other than examining and talking about samples.

Diane was involved with the other children in the wetland group only during the 30 to 45 minute sessions they spent together with me each day. Diane was a tidy, co-operative girl who enjoyed playing games designed for the wetland unit. She did not seem to enjoy collecting samples from the water and often did not spend much time examining the samples that had been collected. Diane expressed great concern about the welfare of the samples and seemed to relate personally to some organisms. She followed instructions clearly and completed tasks to the extent that she thought was expected, as indicated by a comment to Steve after concentrating for fifteen minutes on examining and talking about a water sample, "would you say we're finished?" She worked with a partner, especially when she was working with Steve. Neither of them enjoyed touching the samples, which may in part explain their camaraderie.

Steve was a small, neat and articulate boy. He was quick to offer comments and to get involved in the activities presented. He often gave orders to other members of the group, particularly to Scott. Steve seemed to be aware of the impression he was making on tape, and seemed to be trying to meet adult expectations. He often began interviews with me using polite, literate statements. On day six, he began a tape with "okay, now we're going to be looking at some, um, some water samples, of...Stan is going to, get a sample." Once he became engaged in an activity, forgetting the tape recorders and the adult, Steve would eliminate the commentary. He seemed to move off task frequently, becoming more interested in the equipment provided for sampling than in examining the water samples themselves.

Denise was not originally signed up for the study but she was adamant on the first day that she would like to be in the group. Her interest in studying wetlands seemed to spring from a recently completed school project studying daphnia. She was eager and always volunteered to help out. She seemed much younger than Diane or Steve and less knowledgeable than Scott or Stan. For the first few days, she stayed very close to me. After that, she spent as much of her time with Diane and as little time with Dana as possible. Denise often talked about the "work" to be completed, suggesting that she interpreted the tasks presented as obligations to be completed by the students.

Dana stood out physically from the other members of the group. She had an awkward gait and spindly legs which prevented her from moving as agilely as most ten year olds. I suspected that she had cerebral palsy, which was later confirmed. She was clumsy, which led to several sarcastic comments from Denise. The most striking feature about Dana was her difficulty in speaking concisely and directly. She would often talk around an idea, using a lot of "like" and "um"s. By the time she finally arrived at the core of the idea, she had often lost the listener or her train of thought. In spite of the difficulty, when she felt acceptance, she talked freely. Her understanding about the world began to be revealed through the tapes and provided a particularly interesting example of how one child pulled together her ideas about concepts over a 6 week period, from the beginning of the wetland unit to the end of the follow-up interview.

Categories of Student Ideas

During the two-week wetland unit and follow-up interviews, several concepts were discussed by the students. Some of the ideas which were discussed arose because of questions presented by the interviewer. Other ideas were brought up by the children.

The issue most often introduced by the students involved their thoughts about pollution in the water. Although it became clear that the students had strong views about the presence of pollution it became equally clear that their understandings about it were inconsistent. As an example, although nearly all of the students equated a mid-summer beach closure with pollution, suggestions of the type of pollution causing beach closure ranged from specks of dirt in the water, through garbage floating on the water, to sewage dumping. Many students used the term "pollution" in contradictory ways, indicating that although they felt certain that they understood the term pollution, they did not have a clear image of it.

Other types of understandings about concepts began to emerge during the unit. Students' talk revealing their perceptions about life in a wetland has been arranged into four categories of knowledge. Students' understandings have been classified as strongly held ideas, developing ideas, ideas altered by observation and contradictory or confusing ideas.

"Strongly held ideas" refer to concepts which are discussed by all students in the study in similar ways and were felt to represent a common understanding. Developing ideas refers to concepts which stimulated a range of student responses that seemed to be related to the amount of practical experience and general knowledge they were able to draw upon in discussing their observations. Ideas altered by observation refers to concepts that were easily changed in the face of conflicting evidence.

Confusing or contradictory ideas involve a number of subcategories. Contradictory ideas refer to ideas that are discussed by the students with confidence but in contradictory ways on different occasions, such as ideas about pollution. Confusing ideas are perceptions held by one student that are unusual and unique understandings held by one student. Some confusing ideas seem to be independent of other ideas expressed by the student. Others contain elements of previously expressed ideas but contradict or confuse earlier ideas.

Some concepts are difficult to assign to one category only. Every student held strongly to the idea that water pollution is a major problem but they contradicted themselves and each other over subtler aspects of the problem, such as what causes pollution and what effects it has on the wetland environment. Childrens' understandings about pollution are therefore discussed in more than one category.

Strongly Held Ideas

Two strongly held ideas are discussed below. The first relates to students' understanding that all organisms must eat. The second relates to students' understanding that water pollution is present in wetlands.

Organisms Must Eat

The question "what do you think this organism might eat?" was often asked by the researcher. The answers ranged from "tiny fish," offered by Denise and Dana, to "microbes," as suggested by Stan as the food source for fairy shrimp. Scott and Stan on separate occasions suggested that in order to determine what organisms eat, they could be observed over a period of time, adding different possible food sources until one or more was consumed. Based on his observations, Stan suggested during the second interview that one scud that appeared to be piggybacking another might in fact be using it as a source of food. He did not watch the pair for long enough to confirm or reject his hypothesis.

Steve suggested, when he was forced during the second interview to choose from one of five words to complete the metaphor "the lake is like a...," that the lake is like a factory because "the water produces a lot of stuff that we eat, drink and use and the same for fish...like it makes their food for them and stuff like that" (Appendix D). Steve agreed with the other students that living organisms must eat.

There seemed to be some question about whether very tiny organisms needed to eat. During her second interview, Denise said she didn't think flatworms "need to eat anything," but also suggested that they "might be food for other things." During the follow-up interview, Diane stated that tiny organisms don't eat, they "just drink water." Both Diane and Denise seemed to feel that large organisms must eat, but were unsure about tiny ones. Denise seemed to change her mind in the follow-up interview, suggesting that tiny organisms such as fairy shrimp and water mites "might eat each other, and maybe pieces of duckweed." Diane did not offer any change of view. Dana suggested that tiny organisms eat "itsy bitsy pieces of seaweed."

During the follow-up interview, Scott suggested that all organisms eat food smaller than themselves. He also suggested that changes in the balance of organisms observed in the ecosystem might be due to certain species chasing others for food and forcing them out of the area being examined. Steve agreed with Scott. When asked why catfish could no longer be found in the bay, he suggested:

> Maybe some of the bigger animals are coming along and eating the catfish and then the whole thing changes around. There ends up being more catfish food, the catfish are dead and there are more of the things that eat the catfish, so that's just one small change.

Both Steve and Scott had developed some concept of food chains which they applied to their understanding of ecosystems.

The idea that all organisms must eat to survive seemed to be widely accepted by the students, with some questions about whether or not very tiny organisms eat at all.

Pollution Exists in Wetlands

The term "pollution" arose many times during the wetland unit with reference to a wide range of circumstances. There seemed to be little doubt in the students' minds that pollution was present in the wetland. An outline of situations in which discussions involved perceptions about pollution indicates the wide range of understandings students held regarding the concept of pollution. Steve and Denise suggested during the initial interview that they could see pollution in the water. Steve said "the water's quite polluted. You can tell because it's very coloured." Denise suggested that all the "dirt right underneath all the little creatures" indicated that the water was polluted.

Students' notions about water pollution arose three times during group discussions. The circumstances which stimulated discussions about pollution in the water were dissimilar. The first incident occurred on the second day of the unit while the students were testing the pH of the water in the bay. Stan suggested because the water in the bay had a neutral pH it was therefore clean. He wondered "what would happen if you took a sample around Toronto" and suggested "you'd probably get a three or something."

The second mention of pollution occurred on the fourth day during a canoe trip when an oily patch was spotted on the water. When asked what he thought it might be, Scott replied "pollution" with no further comment. The third discussion occurred on the sixth day of the study when samples of water were found to contain concentrations of flatworms far greater than had been present on previous days. When Scott and Stan were asked to suggest a reason for the increase in flatworm concentration, Stan suggested that "the water's probably polluted," to which Scott responded "it's very, very polluted maybe."

After the summer camp's swimming area had been closed for four weeks, students were asked during the follow-up interview to explain what they thought caused the beach closure. All of the students except Scott connected changes in the lake to pollution. When Diane was asked whether the water was polluted, she said "yes, because my sister didn't go swimming last session...they weren't allowed to go swimming." When the researcher confirmed that that meant the water was polluted, Diane replied "yeah, but now it's not," because the children were allowed to swim again. Denise agreed, saying that the swimming area was closed by "garbage...like cans and smoke" and was later reopened because "the pollution's gone."

Dana also attributed the beach closure to pollution. When asked what she meant by pollution, she said:

> People throwing, um, stones into the water and people, uh, and people throwing, like, um, grass into it. Like that and junk food into it, like junk, like throwing old junk and all that and...if it gets too much it can die. Like the water can, you know, like die.

Dana's comments are discussed more thoroughly within the section "Contradictory and Confusing Ideas."

Stan was most concerned about pollution in the lake created by "factories spewing out wastes" and by the dumping of sewage into the lake. Steve maintained the belief that he could see pollution in the water. When he was examining a water sample during the follow-up interview he said:

> It's hard to see [pollution]. Like this little, these little dots in the water, some of it might be pollution. It's hard to tell which is pollution and which is not because there's so many organisms in the water.

Steve's comments will be discussed further in the section "Contradictory and Confusing Ideas."

It has become clear through the above discussion that even strongly held ideas are perceived in different ways by the students. Students' prior knowledge and experience seem to affect their understanding of concepts. The following section illustrates how several ideas seemed to be understood in different ways depending on students' background knowledge.

Developing Ideas

None of the student's individual ideas changed radically during the course of the study. "Developing Ideas" provides comparisons between the six students involved in the study, examining how their different experiences, backgrounds and approaches to the problem affected their responses. Two general ideas will be discussed in the current section. First, wetlands need to be protected from development. Second, students make observations about wetland organisms based on their past experience. Novice observers tended to focus on few features of their samples while more experienced observers tended to expand their observations to look at the environment surrounding their discoveries. Students' use of language is an important clue to their level of experience and knowledge about wetland organisms.

Students' Understanding about Environmental Protection

Students were asked on the first day to share their understanding about environmental battles. During the initial interview, each child was presented with the picture entitled "Battle for Wetlands," presenting an image of a gavel between a toy bulldozer and a bird's nest with eggs. They were asked to explain the significance of the picture. The explanations illustrate a range of perceptions about the meaning of the symbols. Scott succinctly suggested that the picture represented "don't ruin nature" while Stan suggested that:

> It'd probably be, the decision, whether--this signifies construction, this is, the decision between whether to let construction go ahead and ruin habitat, or not to let it go ahead and save habitat.

Steve connected the symbols with some input from the interviewer:

> The bulldozer represents demolition and stuff...and that's a judge's hammer and I guess that represents the law and stuff like that, the laws and the prophets,

> stuff like that, and the bird's nest, and the leaves and the eggs represent nature and reproducing and going on and on...they're all a part of life.

After he had been encouraged to explain why the gavel was between the bulldozer and nest Steve suggested that "the judges never... they let this do some demolition and let a lot of this stay." Denise explained that "there's forests getting wrecked [by] bulldozers and that, people, governments" and that the gavel "represents court" and that the nest "represents nature". She was not sure why the court would be between the other two.

Diane and Dana had slightly different perceptions of the symbols. Diane explained that the bulldozer was to "bulldoze down the trees and stuff...to build a building there," said only of the nest and hammer that they "represent the products of nature." Dana struggled to explain what each of the items would be used for, but could not think of any connections between the pictures. She suggested that the bulldozer was to "build new buildings or something?" and that the gavel was to "hammer nails into something ?" She seemed very unsure of her responses, ending each as a question. Of the third image she responded "I would say the eggs, they hatch to become, birds and all that," and later said "the nest is made by scraping sticks and all that."

Out of curiosity, I presented Dana with the picture again in the final interview. She had developed stronger categories for linking the symbols, saying "a hammer would be related to [the bulldozer] because they're like tools and all that" and "the grass and all that would be related to the eggs." She developed a link between all three pictures, saying that:

> They're all working stuff 'cause a bird lays eggs, that [the gavel], bangs and all that and that [the bulldozer] pushes dirt and all that.

After five minutes examining the picture, Dana finally said "I don't get it because, you know, I still don't get it."

The students' responses to "Battle for Wetlands" illustrate a range of understanding about the image being presented. Stan and Scott most clearly expressed their perception of the entire picture, while Steve and Denise confidently explained the symbolism of the three parts of the picture separately. Diane and Dana had different perceptions of the three symbols. On a second presentation of the picture to Dana, she expressed a system of classifying concepts that had not been previously used, revealing new information about her sense making process. The students' understanding of the "Battle for Wetlands" picture seems to be indicative of their experience with and knowledge about wetlands.

Novice to Expert Observations of Organisms

From the first day it became clear that some of the students were more familiar with wetlands and had a larger vocabulary for discussing their observations than did other students in the group. The students were given opportunities to work in various sized groups and individually during interviews to examine water samples. Data provided by the students seemed to support the notion that students' ideas progress through stages of development. The next subsection, describing students' perceptions about buoyancy, supports the argument that students' understandings become clearer as their experience and knowledge increase.

Of all the students in the group Stan and Scott had the greatest amount of prior experience and interest in wetlands. They both had had access to marshy waters near their homes. One of the most striking features of both boys, in comparison to the other students, was that from the first day of the unit, they talked about features of the environment in which they had found their samples. Stan often offered clear, scientific explanations for his actions, such as the following comment offered on the second day:

> I took a sample from the bottom which was where the catfish were and so this is just a sample of the habitat where the catfish were swim, living in...that's the habitat, they were in, we found them in anyway.

The image of "Stan is a scientist" is explored more thoroughly below and in the next chapter.

Scott offered fewer comments about his actions than did Stan and he frequently went off alone to collect specimens. He often supplied the group with interesting samples and offered plausible explanations for his discoveries. On the second day, for example, when Scott found a gelatinous mound containing tiny oval bumps, he suggested that it might contain catfish eggs since he had found it in an area dense with the fish.

Stan was concerned about nomenclature and the naming of samples. He liked to be precise about classifications. On the third day of the study two types of fish were discovered by Scott and Stan. Scott said "we have a baby something" to which Stan replied "I think that it's called a gar pike" then changed his mind, saying, "oh yeah. I know what that is now. It's a grass picker." He referred to it later as a "baby gar pike" and later spoke to it, saying "you're a nice little grass pickerel, aren't you?" Although he seemed to be ambivalent about the species name, he did feel it was important to classify it as something more than just a fish.

There are many other examples that illustrate Stan's ability to draw upon prior knowledge, to examine his environment for clues and to apply his knowledge to his examination of samples. While Stan was examining a water sample during his second interview, he said:

> This sort of seems to have a lot of stuff from on land in it, in this water...I'm trying to find out about this. There appears to be a little piece of detritus. It looks like it could be from a tree.

Stan's prior experiences seemed to have provided him with strategies for assessing and discussing problems clearly.

Steve had had little prior exposure to wetlands and he confessed during the second interview that he really didn't like to handle "all this stuff." Diane reacted in a similar way, saying on the sixth day, "oh look, there's a worm. It's really horrible...see, ew, sick." In spite of their disgust both Diane and Steve were willing to examine samples and to comment on their discoveries throughout the unit.

Superficially, Steve seemed to be fairly knowledgeable and verbally adept. When he was working with the microscope on the second day, he said, "[I've] got to check that out under the microscope if I can get it. Oh, I'm going to sample something here." He was unconcerned about the classification of specimens, using such generic terms as "little fish" and "stuff" when referring to objects he was observing. He seldom spent time following through an examination and he often used sophisticated vocabulary in a nonsensical way which indicated that he was aware of scientific terms but not of their appropriate use.

While he was examining seed pods during his second interview, Steve began wondering aloud what they were. When looked at in the water they appeared to be fuzzy, yet they were slippery to touch. When Steve was asked what he thought they were, he replied:

> I guess it's just little specimens, or articles, that have been put together over the years and years and years.

On the second day, when he was examining a water sample collected by Scott, he said:

> Yeah, it looks like dirt and you can see some of it floating around in the water and stuff. You can see a bit of the water particles too. It's pretty interesting. Go to, to get another catfish, Scott.

Steve seemed to be more interested in experimenting with ways to use the equipment provided for collecting and examining specimens than in actually examining samples. Whether he responded as he did because he preferred technology to biology, or because he felt more sure about how to explore the use of equipment than to observe samples taken from the wetland is unclear.

Diane made few comments during the first four days of the unit. One of her earliest comments, about a fairy shrimp being examined was "oh, the eyes are cute." She was extremely concerned about the welfare of the sample organisms, worried that they might die while being examined. She initially had no names for the organisms except "worms" and "fishies," but by the third day, she began to call fairy shrimp the "shrimp thing." Diane concentrated on completing examinations of specimens when she was asked to do so but did not appear to enjoy studying samples simply for her own interest.

Neither Denise nor Dana had any qualms about examining samples but neither seemed to have had much experience studying wetlands. Denise's interest in the study stemmed from a recent school project on daphnia. Throughout the study she called samples either "daphnia," or "dragonfly nymphs," or, if they were hairy, "poppa hairys." She liked to touch and collect samples simply to have them. During a canoe trip on the third day with Stan, Scott and the researcher, Denise kept insisting on pulling lily flowers from the bay but without any particular purpose.

Dana's comments throughout the unit are often interesting, unique and confusing. A number of Dana's comments will be discussed in the section, "Contradictory and Confusing Ideas." Dana offered very few comments in the presence of any of the other students except Denise. Dana did not often classify the specimens she examined and when she did, she seemed to be unsure of herself. On the sixth day, when she was working with Denise, she pointed to a sample and said "that guy that I caught, you know, I, it was sort of like a minnow, or something, or a tadpole, little minnow or a tadpole I suppose." Most of the time, she referred to organisms as "bugs."

The students' responses to the environmental unit were distinct and unique. Stan and Scott were undoubtedly the more experienced biologists in the group yet their approaches to problems were quite different. Stan was able to verbalize his observations, as was Steve. Scott preferred to examine specimens quietly and to supplement his observations of samples by exploring the environment from which the samples were collected. Diane followed instructions clearly and efficiently. Denise enjoyed socializing, often moving from one group to another when she had been paired up with another student. She tended to examine samples for a short while, then move away from the task and return to it later. Dana often remained in one spot, often quiet and appearing to be uninvolved in examining the sample, but willing to become involved when given some guidance either from me or from another student.

Differences in Students' Perceptions

Differences in the students' perceptions about how organisms can live in a wetland can be illustrated by their responses to a question asked of each pair on the sixth day. The students were asked to explain how they thought organisms could remain buoyant in the water. Stan suggested that some organisms "might have an air sac" inside of them. Scott suggested that buoyancy had to do with movement, saying they "would probably sink" if they weren't "doing anything, like swimming." Steve suggested that buoyancy had to do with wave action.

> When the fish move they make waves behind them and when there's a lot of them it makes a big wave, and it keeps them up. So you see, when the fish stop moving over here it stops and then [they sink].

Dana felt that buoyancy had to do with weight.

> Some bugs, little worms are, like, like, heavy and they sink down to the bottom? And then some of them are partially light, and the other ones are all, like, really, really light so they just stay up on the, um, surface.

Neither Diane nor Denise offered an explanation for how they thought organisms remained buoyant.

Stan's clear, concise response suggests that he had information about air sacs used for buoyancy. Scott's response suggests that based on his observations, he has connected the organism's movement with buoyancy, while Steve's observations connected water action with buoyancy. Dana's idea connects buoyancy with weight. It is interesting to note that the other two girls did not respond to the question.

Ideas Altered by Observation

Some of the students' ideas changed quickly in the face of conflicting evidence. The most easily changed perceptions seemed to be those that could not be confused with other concepts. This category consisted of ideas that the students had not thought much about prior to the unit, such as the number and diversity of organisms in a wetland area, and daily changes in the appearance of the bay and in the variety of organisms available for sampling.

Can Shrimp Be Found in the Wetland Area?

During the initial interview students were shown pictures of four common wetland organisms, including a fairy shrimp. I had found several shrimp in the marshy bay on my initial examination of the site. When the students were asked whether they would find shrimp in the bay they all replied either that it would be too small to find, or that it could not live in the bay.

Stan said that "shrimp normally live in salt water." Scott said they would not be found because "it's not like an ocean, it's not big." Steve suggested that shrimp:

> ...like to be out where it's clear...so I'd say probably the smallest body of water we'd find it in is probably Lake Superior, if, at any, I'd say probably in salt water, in the ocean.

Dana suggested that "I've never seen something like that before and I'd say I wouldn't see it." Denise thought she might see one but that it had been "magnified about a thousand times" in the picture. Similarly, Diane felt that it would be "too small to find."

There were fairy shrimp in the samples throughout the two week session. None were found four weeks later so could not be examined during the follow-up interview. All of the students quickly acknowledged that shrimp could indeed live in a wetland.

Can the Wetland Support Diverse Species?

At the beginning of the second interview the students were asked to comment on the most interesting things they had learned about the wetland. Stan, Steve and Dana all commented that they had learned that there was great diversity in the species living in the marshy bay area. Dana commented that "there is a lot of interesting creatures in the lake." Stan noted that "there's a lot more stuff than...you'd notice at first, by just looking at the water." Steve was more explicit, stating that:

> I thought that [the water] was very cold and yucky but I found out that all the yucky stuff was really little fish, and life and stuff.

Denise and Scott were most surprised about the fish in the water. Denise thought that fish were only found "way out in Lake Ontario...not close to, um, an island." Scott was surprised to find that the fish moved around, being found in one spot one day, and not on the next day. He thought that they stayed in one spot. Diane's responses to the question are not recorded because she was unavailable for the second interview.

Four weeks after the wetland unit had been completed, the follow-up interview began with the question, what do you remember best about the wetland study? The responses were more varied than to the introductory question for the second interview. The first part of Stan's interview and his response to the question were lost because of a problem with the recording of his interview. Scott was surprised to have found so few fish in the bay, compared to the number present in the lake near his family's cottage. When asked what factors he thought might contribute to the low fish population in the bay he said "it's shallow. It's kind of in a swamp area."

Diane answered the question at the beginning of her follow-up interview by saying that she remembered "the stick thing with the black things in it." At the time of the interview, I said "oh, when you took the piece of seaweed and shook it and all the things came out of it, you mean?" Diane agreed, but in retrospect I think she was talking about a spongy piece of reed that she had found on the second day from which parallel rows of tiny roots were beginning to grow. My comment effectively stopped further comments from Diane about what she had remembered of the study, except to say "we caught some catfish." It is difficult now to assess whether or not she was intrigued by the diversity of species living within the marshy bay.

Steve, Denise, and Dana provided vague responses to the question of what they had learned, avoiding discussing specific concepts. Steve said "I know much more about this spot. I know more about the water" but would not elaborate on what he now knew. Denise remembered general details of the study and two samples that particularly interested her:

> I remember that you were fishing for, um, stuff that, stuff that we could test. I remember the big root with hair, and the catfish. We went out in the canoes and got lots of samples and we tested the water for pollution.

Dana had the most unusual response of the students. She became extremely distraught when she was asked what part of the wetland unit she remembered best. She spent five minutes trying to remember the study:

> Um, yeah, we had to, like, we were collecting things and then playing with them...the SURVIVAL [game] was fun...do you remember, um, when you had that big, um, root, like, big root, something like that?....I'm trying to remember...I'm trying to think back here. I forget all this stuff!

What the students remembered from the study seemed to be related to their interests as well as to their experiences.

The students all seemed to be impressed during the study by the range of species that could be supported within the ecosystem. Their observations had altered their ideas about the lake.

Does the Ecosystem Change?

The question of whether the ecosystem changes is included under the heading of "Ideas Altered by Observation" because several observable changes occurred during the two week unit. The two most obvious changes were in the concentration and variety of organisms present in samples and in the appearance of the bay itself. Specimens collected during the first week of the unit included dragonfly nymphs, catfish and pickerel. By the second week, the samples contained high concentrations of flatworms and fairy shrimp. Four weeks later, samples collected for the follow-up interview contained small numbers of water mites and little else. The appearance of the bay changed as well. During the first week of the unit the bay was filled with reeds and water lilies. High winds early in the second week caused the plants to be swept onto the shore leaving the bay clear of surface plants.

Ideas about changes in the ecosystem were confused by several students with their observations that specimens put into a stagnant anaerobic environment change. Students' ideas based on their observations of the bottled samples will be discussed in the next subsection entitled "Do Samples Change Under Anaerobic Conditions?"

Comments made by the students identifying changes, or causes of changes in the ecosystem occurred most often during the individual interviews. On the third day of the session Stan suggested that catfish could not be found in the same spots as on the previous day because "I think they probably go deeper, where it's cooler...because now that we're checking for them in the morning they're not there." No other students voluntarily provided reasons for observable changes in the ecosystem. During the follow-up interview they were all asked to comment on changes they had observed in the distribution of species in the samples collected each day.

Some of the students made no comment about changes in the ecosystem during the two week session. Dana did not seem to understand the question when she was asked during the follow-up interview. Denise speculated on changes to bottled samples but indicated that she was bored with the interview when the topic turned toward changes in the ecosystem. The issue was not pressed further.

When Diane was asked to talk about factors that affected the lives of the organisms observed in the samples, she suggested that "the seaweed stuff" was important "because the fish eat the seaweed." She made other connections as well, saying "the sand, because the things grow in the sand, and frogs, I don't know, sleep there. And the water's important." Diane recognized features of the environment that allowed many species to survive within the marshy bay, but she did not provide an explanation for shifts in species populations.

Scott and Steve both suggested that changes in the ecosystem might be caused by changes in the numbers and types of organisms present that would eat one another. Their comments are quoted in the section "Organisms Must Eat." Scott suggested that sometimes there weren't as many "little micro things" in the water as at other times because there could be:

> ...colder water or hotter water. Or maybe...it was just...they weren't with the current that day and went somewhere else. And if the current was with them they'd probably go that way.

Stan agreed with Scott, suggesting that changes in water temperature could have an effect on sample populations. Stan and Steve both indicated that fluctuating pollution levels could affect populations.

Do Samples Change Under Anaerobic Conditions?

The students were surprised and impressed by the drastic changes that occurred in the samples they had saved in bottles for later examination. Roots swelled, lily pads decayed and all of the samples carried the stench of stagnant water.

Dana commented during the second interview that one of the most surprising things she had learned was that "if you put [a specimen] in, like, something, it will dissolve." During the follow-up interview she began to discuss changes in the bottled samples. She began by saying that samples might change "because the lids were on and there was no energy to get out or anything." She later explained that things change:

> Because, like, if, if, like an insect, like, just loves the water, and doesn't want to get out, it changes, right? Like, like, say there was a catfish, right, and it just hated to go out of the water, and all that, and you took it out, and then there was sort of like, um, and then it was, like, uh, and then it changed it, like, it changed the way it looked and all that...if it was in the water, it would stay the same...but then once it gets out, it changes, like into something, like, that'd like land.

Dana discussed her ideas about changes in organisms at other times as well. Her views are elaborated upon under the heading "Contradictory and Confusing Ideas."

Several students noted that the lack of oxygen in bottled samples attributed to their condition. Denise said that "the stink comes from being trapped in a jar. They can't breathe very good." Diane suggested that samples in bottles "deform" because of "the air. There's no air." Stan indicated that "it's sort of going stale. It's not getting washed over by enough water and the water that's in there is getting stale just like it."

Steve offered a complete picture of the process as he understood it:

> Remember the lily? 'Cause everything was eating it, and it was just, so all the, insides of it were coming out and it was, rotting away sort of...so that's basically what happens, except that it got all smelly since it was still in the water...the bottled sample can't get fresh air...if we breathe the same air, it's--we breathe out carbon dioxide, so we can't--we'd eventually die.

Steve understood the need for humans to breathe oxygen and related his understanding to the bottled sample. When he was asked whether he thought certain organisms could survive without oxygen he replied "there has to be because, like, fish live without oxygen. Well, they take their oxygen out of the water." He seemed to be uncertain in the end if any organisms could be anaerobic but he felt sure that something had eaten the lily pad.

There seemed to be confusion about whether organisms in bottled samples were dead or alive. Dana responded that when samples were put in bottles, life was taken from them. When she was asked to elaborate, she said:

> There is something living in there but, like, once they get into the water they're free but, like...he thinks that we're, like, keeping him, like, uh, like we're keeping him in that, in this bottle for, like...like, say he was like fishing, right? And he does something wrong. This is sort of like a jail for him.

The other students had a variety of different explanations for how bottled samples could contain both dead and living organisms. Scott suggested that a disintegrated lily pad looked like "somebody, something ate it up." Steve explained that "things have eaten it. I don't know. They're just munching away at it." Stan mentioned several times that he believed the disintegration of bottled samples was due to micro-organisms but he did not offer further explanations.

Contradictory and Confusing Ideas

Contradictory Ideas

Ideas about pollution provide a good illustration of how students' ideas can be contradictory. Since Steve was the one who most often brought up the issue of pollution, his talk provides the greatest number of examples of contradictions about the concept of pollution. Some evidence from other students can also be found and complements the discussion of contradictory ideas about pollution.

One of Steve's first comments in the unit was to comment that fairy shrimp would not be found in the bay because "they don't like dirty polluted water" and three minutes later he commented that "the water's quite polluted." Denise agreed with Steve on her first examination of the bay water, stating that it "looks kind of polluted." What they described as a polluted look to the water was a yellowish tinge and specks of dirt at the bottom of the bucket used for sampling the water.

Steve began his second interview with the comment that "I always thought that this water was polluted very badly, and I found out that it wasn't." Initially, the comment seems to be an example of an idea easily changed by observation, yet in the final interview, Steve discussed his ideas about pollution in another way. When he was asked to comment on factors contributing to observable changes in species populations in the bay throughout the unit, he suggested that "the pollution rates went up or down." When he was asked to explain his comment, he said:

> Well, it's just, all the things, all the industry that's around, like it has to go up because they're making things in factories day in and day out, so the pollution has to go up at least three, four.

Steve seems on one hand to believe that pollution rates must be continually increasing, yet on the other hand he claims that pollution rates can go up and down, contributing to population changes in the bay.

Steve seems to be certain that there is pollution in the water, but he does not seem to be as confident about how pollution affects the environment or how it manifests itself. His final comment about the issue confirms the last point:

> And even in that just little tiny bucket of water, there's probably some pollution in that too...it's hard to see. Like this little, these little dots in the water, some of it might be pollution. It's hard to tell which is pollution and which is not because there's so many organisms in the water.

Other students in the study seemed to be equally confused about the concept of pollution. Although they agreed that it must be present in the water their ideas about what constituted pollution varied. Stan suggested that it referred to "the spewing out of wastes from factories" and to sewage dumped into the lake. Denise referred to "garbage" in the lake as "cans and smoke" while Dana referred to pollution as:

> People throwing, like, um, stones into the water and... people throwing like, um, grass into it, like junk, like throwing old junk and all that, and, like, if, if

> it gets too much, it can die, like the water can, you know, like, die.

Unfortunately, Dana was not questioned further to determine what she meant when she said the water can die. In the same interview ten minutes later, she described pollution as dirty water by showing me what would happen:

> If you, um, put more things in, like, which is dirty...but watch, right, if you shake, like, shake it, the things are all plugged, like that, and...it starts to move and all the things, things just start to float down. Hm. I would say it [pollution] would be that.

Dana and Steve provided particularly interesting contradictions about their understandings about pollution. The greatest confusion seems to relate to notions about what is pollution and how it can be seen in the water. For some of the students, it seems that they can recognize as a pollutant only something which they can see in the water.

Confusing Ideas

The final section of the chapter discussing the first level of analysis deals with confusing ideas. "Confusing ideas" refers to ideas that are unique to an individual and suggest an understanding of the wetland environment that is personal and unrelated to a scientist's understanding. Dana provided the richest material for discussing confusing ideas so the section refers specifically to her.

As Dana's case develops she appears to be building stories from concepts related to wetlands. It will become clear that Dana uses storytelling and metaphors as a way of making sense of the complex and unfamiliar world of wetlands. More will be said about how she seems to make sense of unfamiliar concepts in the next chapter.

Dana was a particularly quiet member of the group. Until she became comfortable with individuals she seemed reluctant to speak out. During the unit she spoke most freely with Denise and with me. Most of the examples of confusing ideas therefore come from paired work with Denise and from interviews with me.

There seem to be several traits that contribute to Dana's unique responses to problems. The first is her difficulty with language. The more complex a concept she is trying to convey, the more hesitant her speech becomes. It is difficult for a listener to keep track of Dana's train of thought. For example, when she was trying to explain why water organisms do not move when they are taken out of the water momentarily, she said:

> Like, if you got, if you, um, put, like, an, like, animal, like, ones that are in, out, of the water, they kind of, like, ones that are in, out of the water. They kind of, like, they kind of, like, they could, um, like, you know, um, like, like, can't live if you take them out of the water?

Dana seemed to be able to follow her own discourse which suggested to me that she was able to keep an image clear in her mind which she wanted to describe.

Based on her descriptions, Dana's images of many concepts seem to be complex and interrelated. Once she felt comfortable talking to me she shared many of her ideas. She seemed to feel comfortable choosing metaphors to define her thoughts. During the second interview, when she was asked to choose from a selection of five words to explain what the lake was like, she said that it was like a town because "it's like, all these animals that are living in a tank...it would be like...there's families in the water."

The town metaphor was lost as Dana talked and was replaced by the image of "family." When she was asked the question again Dana was offered "family" as one choice of words to complete the statement "The lake is like a..." She continued describing her image of the lake by saying "like, catfish are one family, and bugs are another family...so it would be, family, because of all the creatures that go in to, go to just a normal family."

Another feature of Dana's responses that was not unique to her but was more characteristic of her responses than of the other students' was her ability to animate and to personalize ideas. Several examples are provided below. The first two deal with her concern about the welfare of organisms when they were bottled. The last two examples deal with Dana's understanding about the lake based on her interactions with it as a camper.

Dana had observed that water samples kept for several days in bottles underwent changes. During her second interview, when she was asked to comment on what she thought was happening in the bottles, she suggested that:

> There is something living in there, but, like...*he* thinks that we're, like, keeping him, like, uh, like, like, we're keeping him in that, this bottle, for...like, say he was, like, fishing, right? And he does something wrong, see, this is sort of like a *jail* for him, like, a little, a little *jail*. He might think that.

At that point in her discourse Dana seemed to lose track of her argument, and moved into a description of the bottled sample. Later, during the follow-up interview, Dana again touched on the idea that samples kept in bottles undergo changes, and she provided an animated explanation for what she thought might be happening:

> It would be something like, um, like, they *change* because, like, if, if, like, an insect, like, just *loves* the water, and doesn't want to get out, it changes, right? Like, like, like, say there was a catfish, right? And it just hated to go out of the water, and all that, and you took it out. And then there was sort of like, um, and then it was, like, uh,

> and then it changed it. Like, it changed, like, the way it looked and all that. Because, like, if it was in the water, it would see the same, like, article and all that, but then once it gets out, it changes, like into something, like, that'd like the land.

In both interviews, Dana has built on the idea that organisms have emotions and that they have some understanding about and possible control over the environment in which they have been placed. She attributed to the organisms human characteristics and understanding.

During the second interview, Dana was asked to select from one of three words to complete the statement "I am to the lake as [an animal, a listener, or a storyteller] is to a story." All of the children had trouble answering the question but it did stimulate a response from Dana to suggest that her understanding about the lake revolved around her role as a camper. Once she had stated that she was to the lake as a storyteller was to a story, Dana explained her choice:

> Okay. If the water was a whole bunch of kids, right? In the centre of the hole, i...the camp was, a storyteller, and say, like, he had a microphone, and, like, he would be telling all the kids a story, about the lake or something like that. And then, then, like, the sound would travel, travel all the way around the

> island, where the water is...that's what I think it would be.

Dana's description in fact made her a listener, but by suggesting that the water could be children, she again attributed human characteristics and understanding to the environment, in this case from her own experiences as a camper.

Another example illustrates in a different way how Dana understands the lake based on her own experiences as a camper. When she was asked to explain why she thought the beach had been closed to swimmers for four weeks, she first explained that the closure was due to pollution and then commented that:

> ...when I heard the beach was closed, I said to myself, why would they do that? That's what I thought. Why would they do that, why would they close the beach, if there's kids who swim there? Yeah, and then they, they don't get any swim...like, that wouldn't be fair, you know, because, like, people that like to swim, but if they don't want to swim or if they can't swim, how, how could they cool off, if it's really hot, how could they cool off?

Her understanding about the beach closure was very personal and, in fact, seemed to be unrelated to her previous assertion that the beach might have been closed due to pollution.

When Dana's ideas are analyzed, there seem to be patterns and clarity within her understanding. They are confusing ideas, however, if they are compared to an understanding based on a more scientific perspective. In the next chapter, Dana's perspective will be compared with Stan's to provide a focus for the analysis, exploring in greater detail how two very different students seem to be making sense of unfamiliar concepts. Data from the other students in the study will also be used in the analysis.

CHAPTER 5

ANALYSIS OF STUDENTS' PROBLEM SOLVING BEHAVIOURS

Elaboration of Two Students' Sense-Making Processes

Chapter 4 divided students' talk into different types of ideas--strongly held, developing, easily altered and confusing or contradictory ideas. As the analysis developed, several examples of students' talk indicated that what students say is dependent upon how they think about the problem. An interesting comparison can be made between Stan and Dana. Stan was often able to express his ideas more clearly than the other students because he had a greater amount of experience and knowledge about wetlands than the other students. In contrast, Dana had had little exposure to wetlands and approached the sessions much differently than did Stan.

Chapter 5 discusses how the students, particularly Stan and Dana, seemed to make sense of information they were learning about the wetland. The chapter consists of four sections. The first focuses on examples of how Stan solved problems presented to him during the unit. Stan's skills in observing and reasoning will be termed a scientific approach to solving problems.

The second section focuses on Dana's approach to making sense of information. She admitted that she found it extremely difficult to remember things from the wetland unit. How she gradually made sense of information as she talked and examined samples by creating stories and metaphors will be discussed. Dana's approach to problem solving will be called a storymaking approach. Examples from other students will be used to help make contrasts and comparisons between the approaches to understanding used by Stan and by Dana.

The third section of the chapter examines the students' drawings, particularly those of Stan and Dana, commenting on how the students' pictures relate to their approaches to understanding information about the wetland area. The final section summarizes the two chapters of the analysis. It suggests that the wetland study provides a unique view of students' understanding about a topic related to science education. The summary leads the discussion into chapter 6, the conclusion of the thesis.

Making Sense of Data as a Scientist

The best examples of the students' different approaches to problem solving can be found from transcripts recorded on the fifth day of the study. The students had been paired in their best groupings--Stan worked with Scott, Diane with Steve and Denise with Dana. The discussion in this section begins by describing Diane and Steve's comments about specimens during the paired session, then focuses on Stan's approach to examining a specimen. Although the students all participated in examining the samples, there were differences in their approaches to the task. In contrast to the way Diane and Steve's attention shifted between the most obvious details of specimens, Stan can be seen to focus on one specimen while exploring its environment.

Dana's approach to examining a water sample on the same day is discussed and contrasted with Stan's approach. The discussion about Dana leads into the second section of the chapter, on making sense of data by creating stories.

Diane began the session with the comment "there's something in there...hey, wow, look at all these little fish in the water. Oh look, there's a worm. It's really horrible." Steve's comment about the same sample was "yeah, they seem, whenever you put them in the water, they seem to go over to the side [of the sampling container]." The comments indicate that Diane and Steve were observing and sharing their observations with one another, examining in turn the different types of organisms found in their sample.

Steve and Diane's responses to the task of examining the water sample elicited simple observations and they moved quickly from one specimen to the next. They worked together for 15 minutes, pointing out samples to one another and answering questions I asked them. Diane seemed to work out of a sense of duty to complete the assigned task. As she was examining one of the bottled samples she said, "there's all this foaming stuff, uh, the moss, the mossy stuff. We have to look at this one. It stinks." Ten minutes later she turned to Steve to ask "would you say we're finished?", confirming with her partner that the task had been satisfactorily completed.

When Steve was asked a question by me about how he thought water organisms could breath, he seemed to be very happy to provide me with an answer based on his general knowledge:

> They have gills and stuff, like, and they have to keep swimming all the time, so when they swim, the water goes in their mouth and comes out their gills but, there's something that takes the air out of the water or something...when they're taken out of the water, they can't, there's no water for them to swim through, so they can[t take the wa, they can't take air in.

Although Steve was often able to provide knowledgeable answers to questions, I was left with a feeling that he preferred to be told information, or to read it and report on it, rather than actually discussing observations he had made himself. He supported my view when he commented to Diane that he "hated looking at all these little fish."

Stan and Scott began the session on the fifth day with a commentary into the tape recorder. "We're going to try and get one of those little bugs." "We have some little bugs and now we're going to examine them." The commentary continued for several minutes, but it began to sound like a surgery, with Stan as the physician and Scott as his assistant. Stan continued the commentary:

> They're like very small plankton and they're, uh, some appear to be much longer than others and some appear to be, fairly fat and there also appears to be, sooooomme, very small plants in there.

In response to Stan's comments about the sample they were beginning to investigate, Scott replied "and now we're going to see if we can get other different kinds [of organisms]." Stan's approach to the examination of water samples was unique among the group. He alone made comparisons between organisms and stopped to examine the sampling environment prior to examining individual specimens.

In addition to being aware of the sampling environment and commenting on it, Stan was more interested than the other students in naming the species he examined. As he continued examining the sample with Scott, he said "there's a little, uh, scud." Stan approached the samples both as an objective observer and as an intrigued child. He often addressed the organisms he observed. As he was examining the scud, he said into the container, "did you fish have anything to say about what you are? Come on, don't be afraid."

When Stan was asked a question, he always gave a confident answer. He usually left in his answers a word that would allow him to change his mind should new evidence be presented to him. During the initial interview, when he was asked, based on a photograph, whether a backswimmer could really cling to the undersurface of the water, he said "it's impossible to walk on the surface of water, almost." When he looked at the next picture, showing a drop of water being stretched from the water surface to the legs of a water tiger, he said that the water tiger could cling to the water surface:

> Because it's a larvae and it's, this is, could have been its nest and it could be a weed bed. And it could have its tail stuck...might not have hatched totally yet.

Stan can be seen to be a confident student able to create sense out of unfamiliar experiences by relating new information to his current knowledge base.

Stan obviously enjoyed examining samples and became involved in his work, turning it into a game for himself. Stan had many of the attributes of a scientist. He was curious, he made thorough observations, and when he suggested hypotheses, he looked for clues to support his claim. On the third day of the study when the catfish population had disappeared and two gar pike were found during the cool morning session, Stan suggested that one population had replaced the other:

> Because the water's cooler now and maybe they like the cooler water...I think they probably go out deeper,

> where it's cooler, because, it's just vice versa to the catfish. Now that we're checking for them in the morning, they're not there.

Stan's approach to solving problems presented in the wetland study suggests that he was developing the skills of a scientist. Chapter 2 outlined elements of the nature of science, examining how science is viewed as a discipline. Munby and Russell (1983) argued that the prevailing view of science as a discipline is mechanistic, with the primary questions about scientific events being focused on discovering how things happen. Roberts (1982) argued that a contextual view can be equally well suited as a way of exploring scientific events if explanations for events need to interpreted within a particular context. In the current study, Stan interpreted events within the context of the wetland environment. He sought clear, unambiguous explanations for events, suggesting that he had characteristics of a scientist in his approach to problem solving. His actions supported Robert's (1982) claim that a contextualist view can be a valid approach to understanding scientific events.

Stan demonstrated that he was developing the skills of providing scientific explanations for events. He searched for precise terms to classify organisms, he looked for clues to provide him with information about the environment as a whole to enhance the universal applicability of his claims, and he was able to refer to his previous claims when solving new problems. This last point refers not only to a trait of a scientist but also to a way of processing information. There is more discussion in chapter 6 about how students in the wetland study processed information.

Making Sense of Data as a Storyteller

During the paired session on the fifth day, Dana made an attempt to name her specimen. "That guy that I caught, you know, it was sort of like a minnow, or something, or a tadpole. Like a minnow or a tadpole, I suppose." Unlike Stan, Dana lacked the experience and the confidence to commit herself to an expression of her knowledge. The comment makes an important point about Dana. First, it was the longest statement she had made during the wetland unit to that point. Second, it was a rare attempt by Dana to speak about facts directly.

As the paired session progressed, Dana became increasingly willing to express her ideas. As she gained confidence, she began to create images that seemed to help her to describe what she was thinking. When I asked Dana and Denise to consider how water organisms might breathe, Dana suggested that:

> Um, like, food, the food that you chew, like, it, like, I would say that, there must be this sort of, like, like, like, like, there's this broom that's sweeping

> all of the... and the food that you eat, to keep it...and brings it here.

Dana changed the issue from breathing to digestion. What is most interesting is her use of the image of a broom to explain her concept of digestion. Dana used an increasing number of images and stories during the remainder of the wetland unit and in the last two interviews. She seemed to be making sense of an unfamiliar situation through the use of stories and images.

This section discusses how Dana seems to make sense of data by combining pieces of her knowledge in stories. There seem to be two processes involved in the storytelling. The first involves clarifying an idea by finding a suitable metaphor to define it. Dana often repeated the metaphor as a concluding statement, indicating that she had settled on an idea. A second process, involving weaving observations into stories seemed to evolve as a way of explaining complex and confusing events. This section of the chapter has been divided into two parts, the first dealing with the repition of ideas and the second dealing with the creation of stories to explain events.

Repetition of an Idea

Dana's use of metaphors and stories to make sense of unfamiliar problems became evident during the course of the first interview. When she was asked to examine pictures of water insects, I asked her whether a fishing spider had a fishing pole. She responded that:

> It doesn't, because, um, if it was a fishing pole, it would have a thing there to move down the water with, to the water. I don't think it has that, and, um, like this, it's just like an insect. That's just like an insect.

Once she had reduced the problem element of a fishing pole, and had decided that the spider was just an insect, Dana seemed more confident and more in control. She turned the problem to something that was more familiar to her. There are many examples of Dana's problem reducing behaviour during the course of the unit.

Dana had a number of problems speaking, from problems with diction and vocabulary to problems with clearly elaborating an idea from start to finish. Many examples are recorded of Dana stuttering as she tried to explain herself. In spite of her difficulties, Dana's last sentences were usually clear. Often the phrase was expressed as a metaphor which might be repeated as a final and confirming statement. An example of a final metaphor and confirmation arose as Dana tried to make sense of the fishing spider question, described above. She sounded sure of herself when she said "it's just like an insect" and confirmed her statement immediately after with "that's just like an insect." Later, when Dana was trying to explain the difference between living in a bottled sample of water and living free in the water, she said:

> He thinks that we're keeping him in that--this bottle--for, like, like, say that he was...say that he was fishing, right, and he does something wrong. See, this is sort of like a jail for him. Like a little, a little jail.

Dana's perceptions about changes that occurred in bottled samples are in themselves intriguing and are discussed later. Repetition of the metaphor seems to be a strategy Dana used to settle on an idea.

Creating Stories to Explain Events

One of the first stories Dana created was told to me on the fifth day of the wetland unit. While she was working with Denise, Dana spent five minutes pouring water between an eye dropper and a baster. In the baster she had captured a scud. When I asked her to explain to me what she was doing, she said "if the bug was, like, stuck in there...and you can't move it, and you can use water, like to...to do it." Later on the same day when Dana was left on her own to work, the tape recorded a five minute monologue. As I listened to the tape, I was astounded to discover that she had not stuttered or faltered as she spoke. Parts of the monologue have not been transcribed because wind noises muffled Dana's voice:

> Okay, one of the, um, one of the bugs in that looks like, uh, little, um, nintentions [sic], the thing that would be, um, on, like the, well, on the body, and, of the, of the creature and there would be some sort of like, uh....this looks like, little yellow stuff...a body, in it....it seems to be sort of like a, well, it looks sort of like an inchworm (laughs), but, a worm isn't....I don't think that I would want to be an inchworm.

As Dana was recording her observations about an organism, she was classifying its parts and searching for appropriate vocabulary. Near the end of the monologue, Dana searched for a classification for the organism and provided the metaphor, "it looks sort of like an inchworm." The metaphor, in this case, seemed to replace the name she did not know as she attempted to describe her experiences.

Dana created many stories and images during the interviews. During the second interview, she suggested that "when you look through the, uh, magnifying glass, it looks like, like the bug is living in another city, because, like, when, when it moves around, it ends up moving through the city." Dana not only seemed to be creating a story in the example, but also to be playing with ideas. Playing with ideas seems to be an important tool for Dana in allowing her to retrieve information. When I interviewed her four weeks after the study had been completed she said that she could remember only one thing--a big root that had swelled when it was bottled. I had been working with Dana for 20 minutes before she could begin to talk about her experiences.

During the second interview, Dana explained that an organism trapped in a bottle might think it was in jail. When she talked about her understanding of what happens to organisms trapped in bottles during the final interview, she seemed to still be playing with her ideas. She explained that:

> They change, because, like, if, if, I, like, an insect, like just loves the water, and doesn't want to get out, it changes, right?...like, like, say there was a catfish, right?...and, it just hated to go out of the water, and all that, and you took it out, and then there was sort of like, um, and then it was, like, uh, and then it changed, it, like, it changed the way it looked.

The story came near the end of the last interview after Dana had tried several times to explain how organisms physically change when they are disturbed. She had been trying since the second week of the unit to explain her observation that when water samples are bottled for several days, roots enlarge and leaves disintegrate. Her story seems to be based on her current understanding that samples can be observed to physically change.

Later in the same interview, Dana talked again about samples changing, this time perhaps adding to her knowledge:

> Well, if I, if I got a chance to, see it, like, like, dissolve, um, it would be sort of, like, turn into another shape or something...the root would be, like, getting all brownish and all that, and turning colours and all that, I...that's what it would be for a root...it, it would sort of die.

The word "dissolve" came from Dana's vocabulary and was not used by me during the interview. In the story, Dana seems to be drawing together her ideas about bottled samples--that things change and that things die. At one other point, she had mentioned that pollution could cause the water to die. Death seems to be an image she related to the wetland environment since it occurred at least twice in her talk. Dana seemed to be gradually connecting her ideas and understanding about the wetland area through her storytelling.

Differences between everyday culture and scientific culture were discussed in chapter 2. It was argued that scientific explanations require more precise use of language than do everyday explanations and must be generalizable, while everyday solutions can apply only to specific situations (Hawkins & Pea, 1987). Everyday language can contain metaphors and ambiguities while scientific language must be more accurate. Dana's talk was rich with metaphors and stories, the language of everyday explanations. Furthermore, her explanations were specific to situations. Dana did not seem to be bothered by contradictions in her arguments, nor did she seek a universal understanding about the wetland environment.

Schön (1988) suggested that stories can provide a medium for transforming understanding. Stories can contain metaphors, and can be metaphors that carry familiar ideas to less familiar situations. Dana provided numerous examples of how stories and metahpors could help her make sense of unfamiliar situations but her stories did not remove ambiguities in her understanding. It may be that the study was too short to see such a transformation.

Dana's stories did not always lead to a clearer understanding. Sometimes her stories seemed bizarre and unreal. While she was examining a small sample containing a fair bit of sand during the final interview, Dana began to create the following story, explaining what might live in the sand.

> You know, um, do you know, like, if you've got, like, a little tiny speck of dirt...and, like, say you picked up the littlest speck of sand that there was and, and...and, there was a bare speck of sand, and there was a tiny little door that opened, and there was a little tiny door that opened, and there was sort of like a house, it, it would be sort of like, a little,

> like, something that lived in the house, like, say you got a big rap and the door opened, and, and you picked up a whole bunch of sand, and you, dumped it in there, like, jammed it in there, and there was...and there was a sort of like a fish, like a house, of, that looked like the sand and, get, rock for a house, something like that, and, but there, there's no rock in there, so, the little hunks of sands, or the...Oh, I see a black thing in there, I see a little black thing in there. Do you see it?

Dana seemed to have lost track of the idea near the end of the story. She began telling the story while she was looking for organisms in the water sample. Near the end of the story, she seemed to remember that she was looking for something. Her question redirected both her attention and mine to the task of finding a specimen.

Stan also played mentally as he examined samples, as was described above. When he approached a sample and talked to the organisms, he was engaging in play. From a scientist's perspective, Dana seemed to be making little sense of the environment yet she made observations about the samples and she wove her impressions into stories. There seem to be more similarities between Stan and Dana's approaches to solving problems than is readily apparent through their talk. The last section of the chapter analyzes Stan and Dana's drawings, to look for parallels and contrasts between the students' approaches to understanding the wetland.

Students' Understandings Expressed Through Art

In order to increase the students' choices of tools for expressing their understanding about wetlands, they were asked on days 1 and 9 and at the beginning of the follow-up interview to depict life in a wetland using a sketch drawing. They were invited to add comments and labels to their sketches. On days 3, 6 and 9 the students were asked to observe a specimen and to draw it, focussing on its movement and gross anatomical features.

The students' six drawings contained many references to plants, animals and anatomical features, as well as to pollution, microbes and rocks. A summary of the features of the wetland environment represented in the students' drawings can be found in Appendix J. The discussion of students' drawings focuses on Stan and Dana's drawings in order to look for clues in the students' drawings that contribute to an explanation of what they understood about the wetland environment.

The most outstanding feature in Stan's first two drawings of the wetland was the dumping of sewage and waste (Appendix K). In his first drawing, a sewage truck was dumping liquid and solid waste into the water as two eagles watched. By the second and third drawings, Stan had removed the birds but continued to draw in reeds, crayfish and worms. In the second drawing the sewage truck had been replaced by a pipeline into the water. The final drawing depicted a pond surrounded by reeds with crayfish and snails in the water but did not suggest that the wetland was used as a sewage dump (Appendix K).

Drawing did not seem to interest Stan. He drew only one sketch based on his observations of a specimen. In fact, he did not sketch a specimen. He illustrated how a drop of food dye disperses in water, based on an experiment I had demonstrated, illustrating how surface area can increase without changing the volume of a drop of dye (Appendix K). Dana also drew a bottle filled with green liquid, explaining that "the bottle that is filled with green food colouring has [sic] dissolved." Her drawings are depicted in Appendix L.

Dana's drawings of the wetland contained less detail than did Stan's drawings. Because she attended the second session of the summer camp program while I was working with a different group of students, Dana contributed four sketches depicting life in a wetland rather than the three collected from the other students. Her first drawing was of a fully dressed girl bobbing in the water while a fish swam past her and seagulls and insects flew above her. In the water were the words "green foamy stuff." The next sketch was of a circle labelled "swamp" and a girl with antennae, labelled "space girl" standing beside it. When I gave the assignment , I had asked the students to illustrate life in a wetland to explain to an alien.

Dana's third sketch depicting life in a wetland made no sense to me for a while. She drew a swamp with a caption below it stating "a swamp is sort of like a wetland area?" The swamp contained an insect, seven lily pads and a boa constrictor. I later realized that Diane had also shown a snake in her third wetland diagram and snakes were depicted in pictures drawn by other children I worked with at the camp who were not included in this study. The children must have seen snakes in the water at some time when I was not at the campsite. Dana's fourth drawing of life in a wetland showed a frog and several green lines labelled "leeches."

In addition to her depictions of life in a wetland, Dana made three sketches from her observations of specimens (Appendix L). A sketch made on the third day depicted a catfish with eyes, ears, body and legs. On the day the sketch was made, there were no catfish found in the bay. On the sixth day, Dana drew four dragonfly nymphs. They all had antennae, arms and legs and looked to me like silhouettes of Mickey Mouse. One of the nymphs was placed in a closed bottle. Dana became very interested in and concerned about the consequences of bottling organisms. Her concern was illustrated in the drawing as well as in her talk. On the ninth day, Dana drew "the inside of a leech" as a green stalk with arms. It may have been difficult for Dana to make out fine detail. She wore thick glasses and had trouble using a magnifying glass to see samples.

Stan's drawings were different in many ways from Dana's drawings. In all of Stan's sketches were featured many of the same, unchanging attributes of the environment Stan referred to as a wetland. The drawings seem to be consistent with Stan's approach to the wetland unit based on his talk during the unit. Stan's sketches were clean and simple, symbolizing characteristic features of the environment while focussing on a few important issues, such as pollution in the environment.

Dana's drawings, on the other hand, varied greatly from one sketch to the next. She seemed to focus on only one organism or idea at a time in her drawings. Similarly, when she was talking, Dana found it difficult to remember many things about the wetland unit at once.

Stan was described above as an analytical, scientific thinker. His drawings indicated that he was aware of the interdependent nature of wetlands since he represented plants and several kingdoms of animals in all his drawings. He also indicated that he was concerned about the wellbeing of the environment by his depiction of sewage dumping. The drawings supported, to some extent, the image of Stan as a scientist. In contrast, Dana's drawings focused on one idea about the environment at a time. Her drawings contained elements of fact and elements of invention. The drawings seemed to be consistent with Dana's talk about the wetland, suggesting that she was able to work with only one idea at a time, and that she wove factual ideas into stories as she tried to make sense of unfamiliar information.

Summary of the Analyses

The two chapters of the analysis have discussed what the six students in the wetland unit revealed to me as an instructor and researcher. Chapter 4 categorized the students' talk into four types of ideas. It became clear through the analysis of the students' talk that there was great variation in their general knowledge and in their knowledge about the wetland environment. Differences in students' ideas were categorized into four groups--strongly held, developing, easily altered and contradictory or confusing ideas. These were used to provide a framework for discussing information revealed by the students during the wetland unit.

At opposite extremes of the group's experience were Stan and Dana. Stan had experience, knowledge and appropriate vocabulary to discuss his observations clearly and factually. Dana avoided factual discussion, in favour of discussions that allowed her to create metaphors and weave stories about the wetland using her observations about the environment as the thread and her imagination as the loom.

Chapter 5 analyzed how Stan and Dana, two students with vastly different backgrounds approached the task of examining and talking about water samples. Stan was described as a scientist, while Dana was described as a storyteller. Their approaches to the problem revealed something about their understanding of the wetland environment. Although their views were far apart, it is interesting to note that there were also similarities in Stan and Dana's talk, particularly when they played with the samples as they talked.

During the wetland study, students were encouraged to examine and to talk about their observations within the context of the wetland. Stan has been described as a student who was able to make general and broad observations about the environment and to apply his observations to making sense of specific problems encountered within the wetland environment. Dana also explored the wetland but she seemed to have a much narrower perception of the environment than did Stan. Although both of the students explored problems within the same context, Stan was able to elaborate his arguments more completely than was Dana. As a result, Stan's talk revealed fewer contradictions and a more stable perception of the wetland environment.

The wetland study provided a unique opportunity for examining students' talk revealing their ideas over several days about one topic. Several of the science education research papers which were reviewed in chapter 2 asked students to choose one of several answers to questions about a topic (Arnaudin & Mintzes, 1985; Wandersee, 1985; Gilbert, Watts & Osborne, 1985; Snively, 1983). Although in two of those studies (Snively, 1983; Gilbert et al., 1985) students were encouraged to explain their choice of answers, their ideas had already been focused by the researchers' questions. In neither of the studies were students interviewed a second time, so their ideas were frozen into a single impression provided by one interview. By recording students' ideas over a longer period of time, the wetland study capture more features in the picture of students' understanding than could be revealed by a single questionnaire or interview.

Another valuable feature of the wetland study was its use of several methods for collecting data. Bloom (1990) and Aguirre and Kuhn (1987) used several methods for collecting data about students understanding. Bloom's methods revealed information about how a group of students understood the world, but, as in the studies above, each method was used only once, capturing only a moment of the students' ideas. Aguirre and Kuhn (1987) used their data collecting methods throughout a unit of study about radiation with junior high school students but the focus of their analysis was on teaching rather than on students' understanding. The wetland study was unique in using a variety of methods to examine students' understanding about a topic.

The next chapter reviews the purposes of the study and summarizes the findings, commenting on the success of the study in satisfying its objectives. The success of the study lies in part on the effectiveness of the data collecting techniques as tools for revealing information. A critique of the data collecting methods is provided in chapter 6. Finally, the implications of the study, weaknesses and possible follow-up research questions are presented at the end of chapter 6.

CHAPTER 6

DISCUSSION AND IMPLICATIONS

Comments on What the Thesis Contributes to Research on Students' Understanding

The final chapter of the thesis consists of three sections. The first section reviews the findings of the study, restating its purposes and commenting on the success of the study in achieving its outlined purposes. The second section critiques the value of the data collecting methods used in the study as tools for motivating students to reveal information. The final section of the chapter discusses the implications of the study, suggests some weaknesses in the design and recommends possible follow up research questions.

Review of the Study

The wetland study was conducted as a 9 day unit exploring a marshy bay. The six students involved in the study volunteered to participate as an optional activity within a summer camp program. Working sessions with the students were set up to inlcude daily group activities, a game and time to examine water samples collected from the shore of the wetland. The major data collecting time during each session occurred while the students examined and talked about water samples. Three tape recorders were set up to capture the students' comments as they were working. The students were encouraged to talk as much as possible as they examined water samples.

The two main purposes of the study were (a) to explore how students make sense of concepts related to the study of a wetland area, and (b) to assess the value of several methods used to collect data in an ethnographic study. Three questions were used to outline the first purpose, asking (a) how do students express their understanding of concepts, (b) what are the common characteristics of students' talk, and (c) what processes do students use to make sense of concepts. Questions outlining the second purpose are reviewed in the second section of the chapter.

Summary of the Findings

The students expressed their understanding about concepts encountered in the wetland in a number of ways. Two main methods of communication were available to the students during the unit--drawing and talking. Since none of the students spent a great deal of effort drawing, the majority of information was revealed through students' talk. As the students' talk was examined it became clear that some students were more articulate than others, some had more prior knowledge applicable to the wetland unit than did others, and some had greater confidence in their ability to make sense of information that was presented to them. These three factors seemed to be particularly important as indicators to how students expressed themselves.

Stan was articulate and able to combine his experiences in the environment in order to create explanations about events. He was confident enough to always be able to provide an explanation for events and experienced enough in the environment to know where and how to look for clues to support his arguments. Scott had experience but lacked Stan's verbal dexterity. He spent a great deal of time collecting samples and seemed to like best to observe organisms within their natural habitat. Scott's explanations for events, when offered, were concise and were sometimes supported with evidence from the environment.

In contrast, Steve had an extensive vocabulary but he seemed to have little experience or interest in exploring the wetland environment. He did not seem to have a strategy for making observations and he would often move away from the task of exploring the wetland environment. Like Stan, Steve confidently offered explanations for events but he did not account for variables encountered in the wetland situation. Diane, like Steve, seemed to be confident of her abilities as a student. She used language clearly and well. Although Diane did not express great curiosity about the wetland unit, she exhibited traits of a successful student, able to use strategies to complete even tasks which held little personal interest for her.

Neither Denise nor Dana seemed to be as confident, experienced, or articulate as the other students in the study. Denise often used generic terms to classify organisms, such as "poppa hairy" to define all organisms with cilia or hairs. She enjoyed working with the water samples but her talk suggested that she jumped between observations making few connections between events. Denise and Dana both used many metaphors, comparing their observations made about the wetland environment with more familiar objects. Dana spent much of her time within group activities sitting passive and alone as other students examined water samples. She seemed to lack the confidence to begin a task without support. Often she was not offered the support she needed by other students. Although Dana lacked vocabulary to describe and to classify her observations, she often expressed her understanding about the wetland environment to me through personal stories.

The description of how each student expressed his or her understanding about the wetland environment summarizes the main characteristics observed about each student during the wetland unit. There are few studies in science education that have identified how individual students make sense of information over a period of time. Aguirre and Kuhn (1987) described how one junior high school class made sense of concepts about radiation over an entire unit of study but they focussed on characteristics of the teacher that contributed to successful learning. Bloom (in press) analyzed students' talk as they explored an unfamiliar situation but used only one interview for each student. The wetland study offers a unique look at how a group of students expressed their understandings about selected concepts throughout a short curriculum unit.

Common Features of Student Talk

As the students talked, in spite of large differences in the ways they expressed their understandings, there were also characteristics common to all of the children. The common characteristics were identified most clearly within the analysis of students' problem solving behaviours, particularly as a comparison between Stan and Dana. Although Stan and Dana had had very different experiences and could access different types of knowledge, they shared two important features in their talk and in their play. Both students used language available to them to create classifications appropriate for organizing their experiences about the wetland environment and both students played with the samples as they talked.

Several references have been made within the two chapters of the analysis describing Stan's attempts to name organisms. He recognized a need to use language to sort and classify his observations. Although Dana had access to fewer words for classifying her observations, there were many references throughout the analysis to her attempts to organize and sort ideas. There seems to be support from the data for schema theory, which suggests that learners sort new information into sensible categories (Champagne & Klopfer, 1984; Anderson, 1984). The value of schema theory in assessing the results of the current thesis are discussed more thoroughly in the next part of this section.

Although all of the students used metaphors as they talked about the wetland environment, Dana used metaphors more than the other students to explain her findings. Using metaphors to define terms seemed to be a strategy Dana adopted to circumvent her linguistic deficiencies. Bruner (1986) discussed the role of language as a way of sorting out one's thoughts. Several researchers (Sutton, 1980; Lakoff & Johnson, 1980; Snively, 1987) have argued that students use metaphors to make comparisons between familiar and unfamiliar situations. The wetland study supported the claim that students use metaphors to sort out their understanding.

Bruner (1986) suggested that thoughts are involved in organizing perception and action. In spite of her attempts to make sense of the wetland, Dana's perception of the wetland remained extremely limited. From the beginning of the study to the end, she focused on one characteristic of the environment at a time. Her drawings and her talk reflected her limited ability to pull together her ideas, particularly at the beginning of the follow-up interview four weeks after the study had been completed when she could remember nothing about the study. There seemed to be support for Bruner's theory based on data provided by Stan and other students, but there was also evidence that a student with poor linguistic skills and with little ability to recall her knowledge would have some trouble organizing her perceptions to make connections between ideas.

Play was found to be an important activity for all of the students involved in the wetland study. Some, like Steve and Denise, played with the equipment that was provided while others, like Stan and Dana, involved the samples themselves in their play. Although Stan seemed to be a very serious child, he often talked to the specimens as he was examining them. Dana also played with the samples, but rather than talking to specimens, Dana talked about them as she incorporated her observations into stories. Stan's play involved talking to specimens as characters in his games while Dana's play involved talking about specimens as characters in her narratives.

Several researchers have recognized the value of play in the development of ideas. Bruner (1983) recognized that play could provide a medium for exploration and also for invention of ideas. Hawkins (1965) argued that children need to be provided with equipment appropriate for science discovery and be given time to "mess about" with concepts.

Bloom (in press) also emphasized the role of play in providing students with a context through which they could explore their understanding about an unfamiliar situation. Play is an essential part in children's development of understanding and in their ability to solve problems (Bruner, 1983).

Processes Involved in Sense Making Behaviour

Play appeared to be one process students used to make sense of concepts within the wetland study. Other processes also seemed to be contributing to students' sense making as they examined samples from the same area over several days. The students often referred to their observations from previous days and made comparisons. As they talked, the students seemed to recognize that certain features of the wetland environment would change rapidly while others would not. Their observations seemed to establish rules about what could be expected in a wetland.

Expectations about what may happen in a particular situation are developed as information about a situation is assimilated into existing knowledge structures (Bransford & Johnson, 1972; Anderson, 1984). Many examples of students' talk outline their attempts to make sense of unexpected events, such as the sudden disappearance of catfish from the bay, or the discoveries they made about how specimens changed when they were bottled. The data indicated that all of the students made attempts to explain the unexpected, suggesting that they had all developed a set of expectations about the environment.

The clearest example of how the students established a set of expectations, and rules to describe the wetland environment relates to their perceptions of pollution in the environment. Every student had some sense of the presence of pollution in the environment and how it affected it. Several students suggested that pollution levels could vary in the water and suggested cause and effect relationships. The students provided clues about how they thought about specific problems but they did not always offer consistent explanations for events. For example, Steve explained within the same comment that pollution levels could go up or down, but then stated that factories just keep producing, so pollution levels must always go up.

Larkin and Rainard (1984) suggested that students can create a set of rules to apply to a problem situation and can use their rules to assess the consistency of their current knowledge. Larkin and Rainard applied their problem solving model to physics problems and suggested that their method could be used as a means of explaining physical principles when students were confused or resistant to instruction. While the method may lead students to an examination of the consistency of a physical model, it does not seem to be applicable to a biological system. Although the students had a sense of how changes in the environment could be related to pollution, they were not able to provide consistent explanations for events.

There seem to be two reasons that Larkin and Rainard's (1984) model was unsuitable for solving problems about the wetland environment. First, the environmental system contained too many mysterious elements for the students to be explained by a consistent set of rules. Second, if students are unaware of inconsistencies in their own arguments, then it may be difficult for them to recognize if conditions set by their current understanding of the situation have been met or not. For example, when the students were considering whether or not tiny organisms must eat, they relied upon their existing knowledge about biological systems and their own need for nutrients. The students could not actually see how tiny organisms obtained nutrients and there was no evidence to suggest how, what, or even if the organisms ate.

Inconsistencies in students' ideas occurred throughout the wetland study and students were found to interpret the same situation in different ways. These findings are consistent with observations made by other science researchers (Driver & Bell, 1986; Champagne & Klopfer, 1984) that students can construct different understandings about information than are expected by an instructor. Hawkins (1965) emphasized that children must reach an understanding of scientific principles by their own path if they are to develop insight. Coming to different conclusions about the same events may be an unavoidable step in developing an understanding of scientific principles. As educators have discovered, trying to force students to accept one view of events leads only to resistance and frustration (Linn, 1987).

In order to surmount the inconsistencies in one's understanding about events, the questions seem to have to come from the student. Duckworth (1986) demonstrated that adult students became more interested in examining their beliefs only after they had begun to notice inconsistencies in their own understanding about a situation. Fisher and Lipson (1986) suggested that having students examine their own errors could be used as a tool for encouraging them to reflect on flaws in their logic. As the students in the current study talked about their discoveries, they often edited and questioned themselves. It would be interesting to examine how the students' understanding about the wetland environment could be affected by encouraging them to examine inconsistencies in their own arguments.

As the wetland study progressed it became evident that the students were building an understanding about the environment based on new information and on their current knowledge related to the situation. Analysis of Dana's talk in particular indicated that she was using her existing knowledge to make sense of new experiences. She was intrigued, for instance, by the way samples changed when they were bottled. She returned to the idea several times on different days. As she talked, she spun stories explaining how samples could change. Her stories were different, but they shared some of the same elements, suggesting that she was constructing an understanding from some knowledge base.

Schön (1988) argued that stories often help learners to transform knowledge. Schön's ideas are discussed in the next section. The sense making process used by Dana is described here as an example of schema theory.

Schema theory suggests that learners construct knowledge from their experiences to make sense of the world (Champagne & Klopfer, 1984; Osborne & Wittrock, 1983; Anderson, 1984). Within the wetland study, two particular ways of making sense of the world were outlined. Stan was described as a scientist, while Dana was described as a storyteller. Throughout the unit, Stan used his knowledge about wetlands to explain his observations, while Dana used metaphors and stories to explain her observations. Stan's previous experiences seemed to prepare him to explore his environment in quite a different way from Dana yet in some way they were both found to be building new knowledge by explaining new observations through their available knowledge bases.

It would be presumptuous to imply that one view of the world was correct while another view was incorrect. Both Stan and Dana interacted with their environment and sought explanations for events. Based on their current knowledge, their understanding of the world and their ability to link ideas, they each suggested solutions to problems encountered in the environment. Prior to beginning the study, Stan had a well developed understanding about the wetland environment. His existing knowledge about the world included schemata for assimilating new information about the wetland. Stan was able to readily link ideas about the situation and to recall information about wetland organisms. Dana had had little or no prior experience. She made few links between pieces of information about the wetland and it was extremely difficult for her to recall information.

Champagne and Klopfer (1984) discussed students' inability to construct a consistent explanation about scientific principles. They suggested that students could have "naive schemata," which created loose links between ideas. If students have not been able to sort and to categorize information and to create links between related ideas it can be difficult for them to recall and to consistently apply their knowledge (Champagne & Klopfer, 1984). Data provided by Stan and by Dana in the current study support the argument presented by Champagne and Klopfer (1984).

Three questions were used to outline the first purpose of the current study, asking (a) how do students express their understanding of concepts, (b) what are the common characteristics of students' talk, and (c) what processes do students use to make sense of concepts. Three characteristics were found to be particularly important in explaining how students expressed their understanding. Differences in students' expressions about their understanding could be linked to their ability to express themselves articulately, their ability to relate past experiences to the new environment, and their confidence about their abilities to express themselves. Two common characteristics found in students' talk were their attempts to classify their observations and their play with the samples as they talked. Finally, two processes were described that students used to make sense of the wetland environment. The students were found to create "rules" to explain how events could happen in the environment. A "rule" was defined as a guide used by a student to make a prediction about the wetland environment, based on an expectation. All students, for example, linked levels of pollution to the amount of waste and garbage dumped into the lake. The "rules" used by the students varied greatly and were not always consistent. Stan, for example, could explain that samples kept in bottles changed as a result of stagnant water and reduced concentrations of oxygen while

Dana explained the same problem by saying that organisms can will themselves to undergo physical changes to suit their new environment. Larkin and Rainard (1986) argued that students can create a set of rules and test their consistency. Evidence from the wetland study refutes their claim about the value of using rules to create consistency and reduce differences between students' understanding.

The second process students seemed to use to construct an understanding about the environemt was to sort and categorize information and to build new links in their existing knowledge base. Evidence from the wetland study supported schema theory.

The next section of the discussion examines how well each data collecting method worked in revealing information about students' understanding. The relevance of the techniques is discussed with respect to the design of the study, examining techniques that work best for an instructor who is also the data collector in a qualitative study.

Effectiveness of the Data Collecting Methods

Two questions were used to focus the critique of methods used in the study. First, which data collecting methods produced the most robust data. Second, what were the strengths and limitations of each method. Drawings are discussed first, followed by teacher hand outs, field notes, tape recordings, and the several parts of the interview techniques incorporated into the study. The section ends with a discussion of how the variety of methods led to similar conclusions about the data, suggesting that methodological triangulation confirmed the internal validity of the study.

Although students usually enjoy drawing, it did not seem to be a particularly useful technique in the current study. The students had to use makeshift desks and contend with winds, which contributed to their lack of enthusiasm for the task. The drawings were useful, in one sense, as a different source of data. They did confirm several perceptions I had of the students' ideas from their talk. I would use drawings again when better facilities were available for drawing.

The teacher made hand-outs did not work at all as a method for collecting data. They seemed to be out of place within the context of the study. Although I might use hand-outs as part of my curriculum within a study in my own classroom, I would not include them as a data collecting method except as artifacts of the classroom culture.

Field notes were made daily by me as a record of what had occurred. They discussed details of the curriculum, my feelings about what had been accomplished each day, notes about the students, about the setting and how it was changing, and notes about the students. As I re-read the notes several months after the unit had been completed, I felt that they were adequate in reminding me of the feelings I had as the unit was progressing. It was extremely helpful to re-read my notes as I transcribed the tape and as I began to formulate the analyses. Re-reading the notes provided me with insights I had not recognized at the time I was writing them.

One problem with writing field notes as a participant-observer rather than as an observer was that, even an hour after I had left the site, I felt that I had forgotten important points I should have mentioned. Notes made by a second observer on the fourth day of the study and by me on the same day reflect the difference between the perspectives of the observer and of the participant-observer but they also provide evidence of agreement between two observers' perspectives (Appendices H & I).

The observer's notes caught bits of conversation that I had missed, such as the students' conversations with other campers who were not involved in the study. I was far more concerned about the curriculum and its presentation than I was about the students' conversations while walking between the playing field and the shore. The two sets of notes confirmed some student behaviours, such as Diane's reticence and Dana's tendency to withdraw from the group. Agreement between the two sets of notes helped to validate the observations about the group made by me. There were also comments in the observer's notes about my behaviour as an instructor and how it affected the students' responses. I could not make such objective observations from my position as participant-observer. As I continue doing research in my own classroom, I will focus some attention on improving my skills in taking field notes accurately and completely, and continue to seek outside observations to confirm or refute my own observations about the situation.

The most valuable resource available to me throughout the wetland study were three tape recorders. Although the students' talk was sometimes drowned out by background noises such as the wind or low flying planes, or lost because the students had moved away from the tape recorders, the tapes provided the clearest possible portrayal of each day's activities. As the students became less aware of and less interested in the tape recorders over a number of days, the transcripts became increasingly valuable sources for analyzing students' talk about their understanding of the wetland environment. I learned how to use the tape recorders more effectively, planning activities to limit students' movement away from them for longer periods of time. I would definitely use tape recorders in other ethnographic research studies and would like to augment audio tape with video tape recordings.

The richest recordings of students' thoughts were made while the students were working in well matched pairs and while the students were being interviewed individually by me. When the students were well matched, they talked freely and they seemed to provide for one another an intellectual scaffolding (Greenfield, 1984). An intellectual scaffold provides learners with support, it allows them to accomplish tasks they could not accomplish without it and it is offered only when it is needed.

Stan's interactions with Scott and Steve illustrate the concept of intellectual scaffolding. Stan and Scott both indicated that they had enjoyed working with Stan a great deal. Osborne, Bell and Gilbert (1983) claimed that there is a natural tendency for students to respect and seek the opinions of a student who present clear and consistent explanations for events. Without being obviously aware of his actions, Stan provided the two boys with clear and consistent support. He supplied them with information about the wetland when they needed it, he encouraged them to test out ideas they would not likely have tested on their own and when they did not need support, Stan did not offer it.

Greenfield (1984) suggested that effective teaching involves a process of intellectual scaffolding. The concept of intellectual scaffolding incorporates some elements of Schön's (1988) argument describing how experts can coach novices. Schön's work is discussed more thoroughly in the next part.

When the students were working with me, they all stayed on task, answered my questions, and revealed information about their ideas that was not often discussed when they were working with other students. The interviews were, therefore, an extremely important source of information. The value of each method used for collecting information during the interviews is discussed below.

Effective Methods for Collecting Data During Interviews

Three methods were used for collecting data during the three sets of individual interviews. During the first and the third interviews, students were asked questions about pictures related to wetlands and of wetland organisms. During the second interview, students were asked to complete ten questions demanding a metaphorical response. In all three interviews, the majority of the time was spent examining and talking about freshly collected and bottled water samples.

Questions about pictures was developed as a way of focussing students' thoughts on one part of the picture at a time. It was inspired by Gilbert, Watts and Osborne's (1985) Interview-About-Instances technique. Questions about pictures were useful in the first interview because they provided an initial focus for the discussion about the wetland. The students' answers indicated how much they knew about the wetland environment before they arrived at the camp, and how they talked about ideas when they were asked about issues that were unfamiliar to them. Unlike IAI interviews conducted by Gilbert et al. (1985) students' use of particular words about the environment were not examined to compare students' everyday use of language with scientists' use of language. The linguistic comparison is not as well suited to studies in environmental science as it is to studies in physical sciences.

In the study design it was decided that the same pictures should be shown at the end of the study as at the beginning in order to compare students' responses at the beginning and at the end of the study and to validate the method. In the third interview, I asked some questions differently because the students' experiences and talk about their experiences throughout the unit suggested to me that the original questions asked would be inappropriate. Although the pictures were useful in focussing students' talk on specific ideas during the first interview, the technique did not work well when it was repeated during the final interview.

The metaphor interview technique, requesting students to complete ten statements about the lake with a choice of five words, was not particularly useful. The students did think about their choice of answers for the first seven questions, asking them to complete statements like "I am to the lake as...." (Appendix I). The students provided thoughtful explanations for their choices and some of the information supported the analysis of students' ideas about the wetland, outlined in Chapter 4. As the framework for the analysis developed, it became clear that the metaphor interview did not fit well into the structure.

There seemed to be three major problems with using the metaphor interview as one data collecting tool among many. First, I found that the last three questions I asked were difficult for the students to answer and were frustrating for many of them. These questions were set in the format "I am to the lake as...[a storyteller is to a story; a listener is to a story; or an animal is to a story]." I would not use this style of question again with elementary level students. The second problem with the method seemed to be that it did not work well in conjunction with other data collecting methods used in the current study.

I found that the metaphor interview (Snively, 1983) was time consuming and I was able to use a limited amount of information from the transcripts in the analysis of what students understood about the lake. When I examined transcripts made at other times during the unit, I realized that the curriuclum I had developed encouraged students to create their own metaphors about the wetland environment. By requesting them to complete the metaphor interview (Snively, 1983), I was imposing an activity that was too structured in comparison to the other activities I had used.

The most important information about the students' understanding of the wetland environment was revealed as they were talking about water samples. While they were working with the samples, the students could talk freely. As they talked, they revealed information about how they thought about problems, how they orally sorted ideas, how they created metaphors illustrating their perceptions about their observations, and how they played. I asked them questions to encourage their talk and the students were able to lead the interview in directions of interest to them.

As the students were completing their examination of samples during interviews, I asked questions encouraging them to think about the size and scale of species populations in the wetland area they were examining. I liked the format for interviewing students while they were examining water samples. The interviews were open ended and the students seemed to answer questions most freely when they were able to work with a sample as they talked. They were willing to think about tough questions after they had had a chance to play with materials. Vygotsky (1978) stated that "children solve pratical tasks with the help of their speech, as well as with their eyes and hands" (p.26). Evidence from the current study supported Vygotsky's claim.

The observation that children were able to answer tough questions more easily after they had had opportunities to interact with materials supports Schön's (1984) claim that students need an opportunity to "do" before they can make sense of what a teacher is saying. Schön (1988) argued that there must be a "reflective transformation" through which students use a familiar situation, such as playing with water, to explore a new context, such as explaining how the water can support living populations.

The transformation creates new sense for the student about the situation and the experience, which can be demonstrated through their talk. The students' interview transcripts in the wetland study contained a number of metaphors and stories. Schön (1988) argued that reflections about observations are often embodied in stories. Interview transcripts and observations about students' behaviour during the interviews supported Schön's (1984, 1988) claims that students need to interact with materials in order to reflect on their understandings and that metaphors are used as tools for transforming understandings.

The value of each data collecting method used in the study has been reviewed. Tape recorders were invaluable for recording data and for increasing the internal validity of the study. Field notes were helpful in returning me mentally to the research site several months after the unit had been completed. The drawings revealed some interesting information but they were not completed under ideal conditions. The teacher created hand outs were useless for collecting data.

Asking questions about wetland pictures helped to focus students' ideas and talk during the first interview, but they were not particularly helpful during the final interview. The metaphor interview generated a fair amount of data but it did not provide information that fit well into the framework for the analysis. Open ended interviews allowing students to talk as they manipulated materials revealed the greatest amount and the richest information regarding students' ideas about the wetland environment.

As the analysis progressed, it became clear that information about the students was revealed through a variety of methods. I could refer to transcripts made using different data collecting methods to confirm my perception of the students' understanding about the wetland. The overlap of information produced by different methods suggests that methodological triangulation added internal validity to the wetland study. This confirmation of internal validation suggests that a long term study conducted by an instructor acting as a participant-observer can represent a valid piece of educational research. It also suggests that there is a place in educational research for more research done in classrooms by teachers.

The final section of the chapter discusses implications of the study, suggests weaknesses in the study's design and suggests questions that could be followed up in a subsequent study.

Conclusions

The major implications of the study relate to observations made about how students process information. The students involved in the wetland study came from a variety of backgrounds, had a range of experiences applicable to the wetland study and held different understandings about the world. There were some common characteristics in the processes used by different students to make sense of information. Even though they were all exposed to the same situation for nine days, the students' understandings about the wetland environment were very different. The differences between students' understandings suggest some implications of the study.

There were several data processing strategies used by all students involved in the wetland study. They all played with the materials presented to them, they all searched for ways to organize and categorize their ideas as they talked and they all created metaphors to describe their observations. The students seemed to develop a set of expectations about the wetland environment.

As the unit progressed, it also became clear that all of the students made reference to earlier observations about the wetland environment to confirm and clarify their understanding about new data. One of the most valuable features of the wetland study as a research study was that it encouraged students to examine one topic for an extended period of time, allowing the researcher to discover how students could create knowledge and make reference to their newly stored knowledge as they made sense of related information.

In spite of the fact that they used the same mechanisms for processing information, the students came to very different understandings about the same situation. Although all of the students had some expectations about the wetland environment, there was a range of views. Some students, like Stan, were able to discuss interactions between several features of the environment and to describe their understandings from a fairly consistent perception of the wetland. Others, like Dana, could concentrate on only one feature of the environment at a time. Their explanations about specific events were inconsistent with explanations about other events occurring in the wetland environment. When Dana did follow one situation over several days, such as her talk about what happened to bottled samples, her ideas were found to contain a certain amount of consistency in themselves but bore little resemblance to a scientific perspective for understanding the situation.

There are two implications for elementary science teachers. Students who are already articulate and knowledgeable when they begin studies can readily assimilate new information. Students who have well developed schemata can create links between ideas and can be encouraged to examine gaps in their own perceptions. Students who are not as articulate or as knowledgeable cannot readily assimilate new information and cannot use their thoughts well to organize their perceptions.

It was also found that students who were articulate and confident tended to support one another. Stronger students seemed to be most willing to help their weaker peers when they felt that each person could benefit from the relationship. Weaker students who had trouble articulating their views and who had little confidence tended to be ostracized by the others. Peer interactions seemed to provide the students with opportunities to talk about their ideas. Weaker students did not get the same opportunities and their ideas were not as often challenged or supported by others. Evidence from the wetland study suggests that all students need to talk about their ideas through play and with peers to organize their understandings.

Two suggestions are made about elementary science education, based on the findings of the study. First, the teacher can provide students with materials related to understanding a set of scientific principles and opportunities to play with the materials while instruction continues. In addition to offering students opportunities to play, the findings of the current study suggest that it is equally important to provide students with opportunities to build their vocabulary for categorizing and organizing their ideas. Students need to be encouraged to talk about observations.

Weaknesses of the Study

Several suggestions for improving the study have been discussed in the last section, outlining the value of each data collecting method. Field notes could have recorded more detail and reflected more information about the dynamics of the study as it developed. Some of the data collecting methods were time consuming and not particularly useful. Their presence in the data created confusion about how to design the analysis. The two most important weakness in the design of the study were the choice of setting and the length of the unit.

The setting was chosen for practical reasons--uncertainty about where I would be working in September and the need to complete the data collection before losing a full year due to scheduling complications. I am grateful to the camp directors for allowing me to fit my study into their camp schedule, but it would have been extremely helpful to have had a place where the students could sit to draw, or to write, or to examine samples quietly and out of the wind. The unit was long enough to complete the tasks I had provided but it was not long enough to fully examine how students' understanding about concepts could be shaped over time.

Suggestions for a Follow up Study

Several questions occurred to me as the analysis developed. Two of the main questions I would like to consider based on the findings of the current study are:

1. How can students' metaphors be used to build their vocabulary to increase their ability to talk about observations as scientists?
2. How can a teacher structure students' play with materials to encourage talk about observations among the students, in the absence of the teacher?

Other questions I would ask within an ethnographic study as a participant-observer would be:

1. How is the teacher's perspective interpreted by the students?
2. What is the teacher's influence on the student's understanding?

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APPENDIX A

SUMMARY PROPOSAL

Summary of a Study to Understand How Students Learn

I am a graduate student at the Faculty of Education at Queen's University. As part of my Master's thesis, I am currently developing a study unit about lake ecology for children aged 10 to 12 years. The purpose of my research is to examine a number of ways of finding out exactly what students understand about what they are learning. I am particularly interested in exploring how the language that children use to describe their experiences relates to their understanding of concepts being taught in a class.

I have written this summary because I would like to teach the lake ecology unit during the summer and to work with a group of ten to twelve students for two weeks. Since the unit I wish to teach involves a wetland habitat, it should be presented in a setting such as a summer day camp programme. The next two pages summarize the reasons for the study, its purposes, the methods I will use in teaching the unit and what I will be doing with the students, including ethical issues related to the study.

As an elementary school teacher, I have been troubled by a number of students whose progress in school is difficult to monitor because they understand concepts differently than the experts in a subject area. The problem is particularly prevalent in science because students are often presented with "laws of nature", which in fact are simply explanations that stand up to criticism. Often students have a non-scientific understanding of the same concepts yet they accept the "laws" as presented by an authority in the subject even if the logic of science makes no sense. When that happens, it becomes extremely difficult to excite students about learning science.

The current study proposes to examine students' orientations and understanding about science concepts as they learn about lake ecology. I want to listen to students talk as they play with ideas, and look at how they make sense of a wetland environment. The two purposes of the study relate to methods of assessing students' understanding and to how instructional methods affect students' understanding.

All of the students in the lake ecology group will be asked to complete an interview with me prior to the first class. I will interview the students at the day camp and each interview will take no longer than one half hour. The initial interview will give me an opportunity to meet each student and will provide me with information about how each student views lake ecology initially. For example, is the student concerned about the environment, or is the lake most important because it is fun to play at the beach? Based on the interviews, six of the students in the class will be selected as students whose work will be collected and analyzed for the purposes of the study outlined above.

The lake ecology unit will be the same for all students in the group, including the tasks that are designed for collecting data for the research study. Data on the six students selected for the study will be collected by a number of methods. They will work in groups and individually to complete tasks, to perform experiments using a variety of materials supplied by the researcher, to solve puzzles given a number of clues, and to share their discoveries by making short presentations, by writing stories, and by drawing.

The six participants in the research study will be interviewed about their understanding of the main concepts being explored within the unit at different times during instruction. The participants will be asked to solve a problem during an interview and to talk about their method of working through the problem as they complete it.

Field notes will be made throughout the unit and will include notes on observations about the students, photographs of the students and tape recorded discussions and interviews with the students. The six students whose work was selected for analysis will be asked to participate in an interview four weeks after the lake ecology unit has finished, in order to assess whether their conceptual orientation has changed from the orientation held prior to instruction and from the orientation expressed at the end of the curriculum unit.

Prior to beginning the study, all students in the course will be given a note describing the study for them and for their parents. Each student must return a note signed by his or her parents consenting to the student's participation in the study. Subjects' rights to anonymity will be upheld. Prior to working with the students, the study proposal will have been passed by Queen's University Ethics Committee. Subjects in the study will be treated fairly and with consideration.

I would greatly appreciate the opportunity to work with a group of 10 to 12 year old campers to provide them with a chance to explore a water environment, and to provide me with a group to study.

APPENDIX B

CONSENT FORM

May 24, 1989

Dear Parent or Guardian,

I am a graduate student at Queen's University. As part of my studies I want to work with children aged 10 to 12 on a wetland ecology study. I will be working with a small group of children at Camp *********** during the first camp session in July. I would like to have your permission to use any information that your child provides toward my study.

In order to better understand how children think and learn, I will be working closely with a small number of children in my study. As a teacher, I believe that I can provide some insights about how children learn biological concepts. In order to do that, I will need to observe children as they work. I will be using cassette recorders to aid my research. I will also collect samples of children's writing and artwork. All information that I collect will be confidential.

Your child may refuse to participate at any time during this research project with no risk of such a decision being held against him or her. If you have, now or later, any concerns or questions about the research, feel free to discuss this with me by phoning me at 549-7958 and/or with the Dean (Prof. Paul Park) or his delegate.

Thank you for your support.

Sincerely,

Carol Hulland
BSc, BEd

PLEASE RETAIN THIS SECTION FOR YOUR RECORDS

PLEASE RETURN THIS PORTION

I, ______________________________, give permission for my

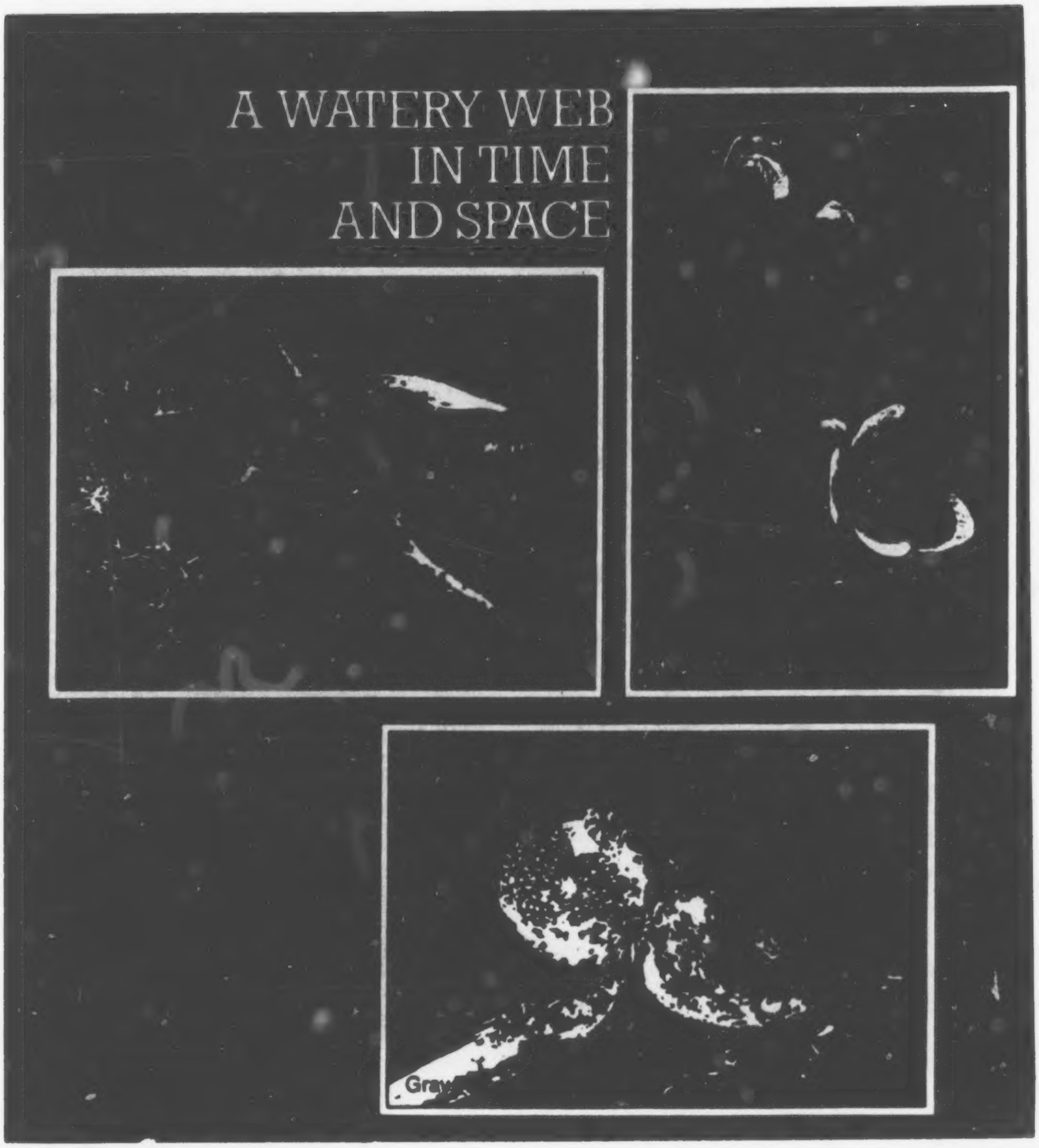
child, ______________________________, to participate in a study being conducted by Carol Hulland of Queen's University.

____ ______________
(Parent or Guardian's Signature) (Date)

APPENDIX C

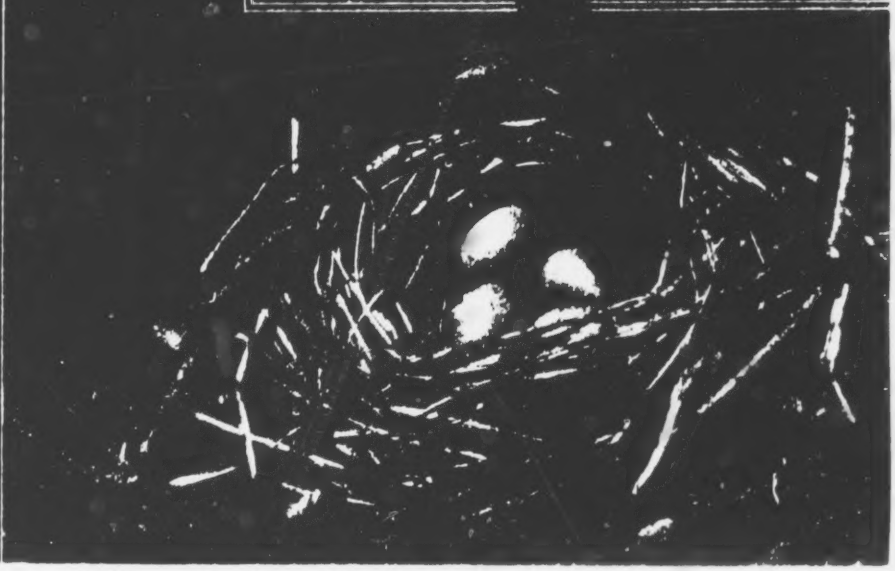
Photographs Used During Interviews

Source: Ontario Federation of Naturalists (1979, summer).

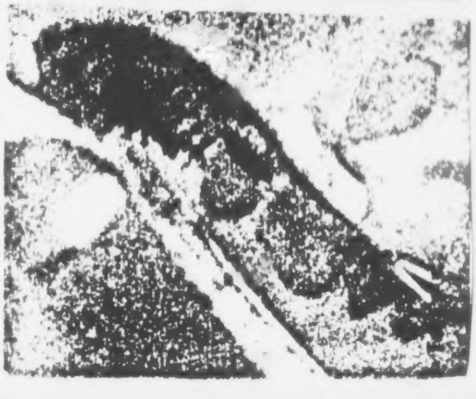


FOR WETLANDS

The fate of wetlands often hangs precariously on the might of opposing forces – the developers vs the preservationists – with the courts sometimes summoned to referee the confrontations. The following stories of three well-known wetlands, Rattray and Second Marshes and Minesing Swamp, together illustrate the truth of the adage that while battles may be won, the war is far from over. Seldom do clear winners emerge. The only real losers, though, may be the embattled [illegible] wetlands. Drained, replaced, farmed and flooded, they and their myriad wild[illegible] inhabitants have no second chance at survival. Their loss [illegible] diminishes all of us.



COOL... CLEAR... WATER



APPENDIX D

Metaphor Interview Questionnaire

Source: Snively, G. (1983)

The questions were asked orally, such as "moss is like a..." The students were then given five colour coded cards for each question and asked to choose the one that best completed the sentence.

PartI: The lake is like a...

i)	ii)	iii)	iv)
factory	potluck dinner	farm	family
painting	necklace	dance	jewel
house	town	graveyard	spaceship
battleground	playground	hotel	garden
legend	song	gift	patchwork quilt

Part II: **** is like a...

i) moss	ii) sun	iii) mud	iv) lake water
garden	jewel	pillow	diamond
banana peel	furnace	tunnel	factory
curtain	gift	piano	dance
forest	lamp	potluck dinner	soup
patchwork quilt	factory	city	theatre

Part III: I am to the lake as...

i) a lock is to a necklace
a bead is to a necklace
string is to a necklace

ii) leaves are to a tree
roots are to a tree
bark is to a tree

iii) a storyteller is to a story
a listener is to a story
an animal is to a story

APPENDIX E

TEACHER HAND-OUT #1

July 5, 1989

Name:______________________________________

How old are you?_________

What is your favourite summer activity?____________________

What new thing did you find out about the water around **** Island?

____

____

Take a look at the water samples.
DRAW! What do water bubbles look like in:

a) a full jar? b) a half full jar?

AN EXPERIMENT

Jar A: We filled one jar completely full of lake water.
Jar B: We filled one jar half full of lake water.

Make an hypothesis.
If we keep our samples bottled for a few days, where will we see living things?

	YES	NO	NO DIFFERENCE
Jar A			
Jar B			

On Friday, we'll open the jars and see if you were right!

APPENDIX F

TEACHER HAND-OUT #2

Becoming Acquainted With a Specimen

CHOOSE AN INTERESTING SAMPLE.

TRY TO FIND OUT HOW IT MOVES.

DOES IT HAVE EYES? LEGS? AN ARTICULATED BODY?

AFTER YOU HAVE TAKEN A CLOSE AT IT, DESCRIBE IT!

[list three words that describe how it looks]

____

____

____

THEN DRAW IT!
[label features like eyes, etc.]

APPENDIX G

WETLAND UNIT CURRICULUM OUTLINE

The outline presented below was prepared prior to the beginning of the study. Although it was followed fairly closely, there were some changes. Day 5, for example, turned out to be an indoor day. I took a water sample to the students but the auditorium turned out to be a terrible place to run the study, so it was essentially a lost day.

I. Day 1 (Tuesday)
  A. meet students, introduce self and study
  B. hand out paper and pencils - students given 20 minutes to depict their view of "Life in a Wetland"
  C. individual interviews
    1. ask students "yes" or "no" questions about wetland pictures, then encourage to talk about response
    2. examine a freshly collected sample of marshy water
    3. bottle one sample of water in Mason jar - to be examined by students in a few days
  D. TAPE RECORDING, DRAWINGS, FIELD NOTES, INTERVIEWS
II. Day 2 (Wednesday)
  A. start with a game of "Survival" so students get to know each other and get a perspective of populations in the wetland environment
  B. experiment: collect full and half full jars of marshy water - notice differences in bubbles and examine again after a few days
  C. water sampling: use Hand-Out #1 to encourage students to think of words to describe their observations and to draw one of their observations
    1. students working in smaller groups (3-4 per group) for 20 minutes
    2. finish with 5 minute wrap-up and sharing time
  D. TAPE RECORDING, HAND-OUT, DRAWINGS, FIELD NOTES
III. Day 3 (Thursday)
  A. play "Survival"
  B. water sampling: begin to encourage students to look for clues to how organisms eat, protect themselves, hide, reproduce, MOVE - give them Hand-Out #2 to make notes and drawings
    1. students working in groups of 3 for 20 minutes
    2. 5 minute wrap-up
  C. TAPE RECORDING, HAND-OUT, DRAWINGS, FIELD NOTES
IV. Day 4 (Friday)
  A. begin with new game, "Environmental Hide and Seek"

B. examine bottled samples collected on Days 1 and 2
C. water sampling: in small groups again
    1. today, focus on comparisons with other days
    2. collect new samples for bottling and examining later
    3. introduce pH testing kit
D. canoe trip for 3 students - look at marshy bay from a different perspective
E. TAPE RECORDING, FIELD NOTES

V. Day 5 (Monday)
    A. begin with "Survival"
    B. water sampling - working in partners
        1. look for a situation in the wetland that can create conflict in students' understanding about life in the wetland
    C. examine samples bottled in first week
    D. TAPE RECORDING, FIELD NOTES

VI. Day 6 (Tuesday)
    A. begin with game of students' choice
    B. water sampling: working in pairs
        1. focus on movement of organisms and new or different observations from previous week
        2. draw and label one organism after careful observation
    C. TAPE RECORDING, FIELD NOTES, DRAWINGS

VII. Day 7 (Wednesday)
    A. start with new game, a competition to be the first team to create a circle around two large neighbouring trees using only scissors and one letter sized sheet of paper
    B. individual interviews
        1. questions about what has surprised students about the wetland
        2. metaphor interview
        3. water sampling - talk about a sample as it is examined
        4. bottled samples - talk about observations
        5. questions to encourage speculation about numbers of organisms living in the wetland area
    C. TAPE RECORDING, FIELD NOTES, INTERVIEWS

VIII. Day 8 (Thursday)
    A. begin with demonstration - dispersal of one drop of green food dye into water - increasing surface area without increasing volume
    B. water sampling: in pairs
        1. focus on how small organisms can function, considering their compactness (consideration of volume and surface area)
    C. TAPE RECORDING, FIELD NOTES

IX. Day 9 (Friday)
    A. wrap up session

    1. begin by drawing a picture to illustrate "Life in a Wetland"

B. water sampling - whole group

    1. look for anything new in water, not previously encountered

C. TAPE RECORDING, FIELD NOTES, DRAWINGS

APPENDIX H

PARTICIPANT-OBSERVER'S FIELD NOTES, 7/7/89

I stopped at Radio Shack to buy a magnifying glass and 4 "C" batteries. They no longer stock the small magnifiers I wanted, so I bought just one large one.

Mary (the second observer) arrived at the camp at the same time as I did--shortly after 10:15. We put out the materials and I brought out the samples we had put away two days earlier to examine again. Some of the samples of water from the site have a strong sulphur smell. I didn't go into it today, but over the next week, I want to develop some concepts regarding the samples themselves--how we have altered the ecosystem and changed such things as influx of nutrients, concentration of oxygen, and so on.

The five students from the "G" group (the Gophers) joined us promptly at 10:30. The remaining "gophers" in the study are Denise, Dana, Steve, Stan and Scott. In some ways, either because she is isolated from the other members of her group during these sessions, or because she is slightly older, or for other reasons, Diane remains somewhat aloof. I will write more about this farther into the notes.

Game

We began with a game in which all but one person was to hide while the remaining one searched for the others. The purpose of the game was to give the group an opportunity to feel the environment from the perspective of a small, ground-bound animal. When we talked about it informally, both Stan and Denise mentioned that they had felt small and insignificant when they crouched low in the grass while playing "Survival."

The other purpose for the game was to give me a chance to collect Diane. Her group was working in the field and her leader had not remembered to send her over to join us at 10:30.

Dana volunteered to be the first person to search for the others. They were given a few minutes' head start. Dana apparently ran past each of them, looking neither left nor right of her path. Scott said that he had been standing just off the path to her right and she had not noticed.

After I had called Diane, I sent Diane and Dana both off to search for the others. When I went down the path a minute later, all the kids had gathered and were returning to the field on their own. Dana, meanwhile, had walked to the far end of the path, but did not seem to be searching for anyone. We waited for her before we returned to the work site.

Samples

I turned on the tape recorders when we got back to the sample collecting site. We looked briefly at the samples collected earlier, and I asked the students to take a look at the work sheet I had prepared for them. I then left them to work as they wished, but checked in with each of them over the next 30 minutes.

During the session, two boys came over to watch. One of them hung around the day before as well. Today, he told me that he wished that he had signed up for the group. That seems to be a good sign that the group seems happy and involved in what they are doing.

Denise: I looked at the shrimp we'd left in a water filled petri dish. It had shed its coat overnight and was still alive. Denise immediately made a drawing of the organism. She did not refer back to the sample as she drew. She seemed to be drawing to satisfy my request, but wanted to get it over with quickly.

When I asked Denise if there was a difference between the shrimp and its shed coat, she said there wasn't any. When she finished talking to me, Denise moved to the water and remained there looking for interesting specimens for most of the rest of the session.

Dana: She wandered around for a while, vaguely looking at some of the bottled samples. She watched Steve work with the microscope for a while. I pointed out some samples to Dana, suggesting that she look for specific features of the organism. She drew one organisms and told me it was a catfish, but there none were caught this day. She gave the specimen feet in her drawing.

Diane: Diane remained aloof. She would not sit down to examine samples. When I asked her to look at a spider on the surface of the water, she did not turn her head toward it to look more closely. Diane did comment on the shrimp's cast off skin and she offered some suggestions about it. Did I limit her response? I must check the tapes for clues.

Diane's drawing was of the shrimp shedding, drawn shortly after I had asked for a drawing. After it had been completed, she wandered around, not seeming to have any particular focus for the remainder of the session. No...near the end, I put the water spider into a glass jar and showed it to Diane like that. She commented on its silvery belly and became animated as she talked.

Stan: Stan was searching for catfish again today. At one point, Diane pointed out to me that there were some catfish near the shore. I tried to catch them using a seive but they got away. Stan and Scott came down and looked in the reeds but they could not catch any, either. They did catch what Stan called a gar pike. They also found a water spider.

Stan spent most of the session in the water, collecting samples. Among other things he found a tuber with small roots on it. This was put into a sample bottle for later examination.

Stan did not draw a sample. Did he avoid drawing, or just not have time for it? Keep watching for clues.

Scott: Scott joined Stan for a while in the water. He came back to shore and began looking at the bottled samples. He seemed to be particularly interested in the fish Stan caught. His drawing was of the gar pike.

Scott wanted to work with the microscope near the end of the session. He did not stay with it for very long.

Scott is so quiet that it is hard to know what he is thinking. I will have to watch him more carefully next week.

Steve: Steve wanted to examine the bottled samples using the microscope. He called me several times to look at what he had found. In the end, he settled on drawing the gar pike.

Questions arising from the session

All of the drawings were very superficial. The most elaborate was Steve's, but I am not sure whether he was drawing it from his memory of a fish or from his observations. I am wondering whether the kids just want to rush to get back to the more interesting task of examining and collecting water samples. I want to push this idea further, asking for other drawings but focusing on greater detail in their drawings.

While it is true that I now have a select and biased group of six students, I am wondering how much of their interest is based on prior experience with biological exploration, and how much on other factors (like, they've been to this camp for the past four summers and are bored to death with the basic routine).

Denise, Scott and Stan have had some experience. Denise is interested in daphnia. Stan and Scott have caught catfish before. How much prior exposure have Steve, Diane and Dana had? Is their inexperience affecting the ways in which they interact with the environment?

Things to Follow Up

1) explore the concept that by changing factors in the ecosystem, we can produce noticeable changes in the system (eg. in bottled samples).
2) push the drawings. How does drawing and looking for details to draw support students' understanding about the wetland? Use as a problem solving situation.

APPENDIX I

Second Observer's Field Notes
July 7, 1989

Arrived at the camp 10:20. Four groups of children with leaders.

The groups of children begin to move to different areas. One girl comes over to Carol's group. They are known as the "G" group. The girl tells C. that they were just swimming. It's an overcast day about 26°C.

It's a small peninsula surrounded by water.

1st girl speaks to me. We have to miss archery
me - Do you like archery?
girl - No
me - Then it's okay to miss it?
girl - yes

Girl looks at specimen jars and pulls them out of crate one by one.

Boy pulls some equipment out of C.'s bag - camera and microphone

C. hands out books to children. Five children here presently. Children smell jar that [sic] C. says "smell this, it stinks."

me - sit down - outside of group

C. instructs - 1st play a game, then come back and look at specimens and draw

girl - I'm not good

Girl guesses game...can we play "Survival."

C. - hiding game

All have tape recorders - turn off.

Walk to game area. Children watch carefully.

3 guys talk re-archery..."I vow there'll be no more yellow in the middle of the bull's eye at the end of the summer."

girl Dana - has a limp (CP?)
- talks to C. - "you wear the same shorts and T-shirt all the time."
D. goes to look for other four children who have hidden. (The one she finds 1st has to then find next child.)

C. goes to find Diane
me - have not been introduced. Standing by self waiting for children and C. to come back from the bush.

10:42

One leader with grey sweatshirt walks by, nothing said. A different group of children playing archery.

discussion with C. This game - purpose to teach re- hiding places in nature - yesterday, crept low to see a different perspective

C. goes and finds 5 children. Dana other end of park calls her back. They wait for Dana on command of C.

2 boys go to watch archery.

1st girl talks to C. - tells her how other child found her because she saw her hair

C. states she brought a jar in and more stuff as specimens. Walk by other group - other boy says to boy in "G" group "How come you're not doing archery?"

Four children look at specimen container. One boy (white shirt) stands on edge, looks over shoulder.

1st girl asks if she should turn recorder on.

On command of C. - observe specimen and discuss
Other boy holds microphone. Kids standing, moving around.
me - sitting on ground

1st girl asks again if she can test water. 3 other boys walk by - "boy it stinks here." 3 guys go with C. to "see if they can find catfish."

Girls stay behind to draw some pictures.
me - have not said anything

Dana asks - "are we supposed to draw what we think we saw?"
me - "I'm not sure. That's what it sounds like she wanted you to do."

1st girl holds microphone and tape recorder is on. "I know what I'm going to draw."

Other two girls sit on either side.

C. checks on girls

White shirt boy stays behind to observe specimen

10:51

1st girl done picture - takes it to C.
Dana draws quietly.
C. suggests a specimen for Diane
Dana speaks to researcher - "I can't draw."
me - "Can I see? You labelled it, that's neat. What kind of bug is it?"
Dana - "It's a catfish. Is that what we were supposed to do?"
me - "I guess it can be specimen if you catch it."

Dana walks over to C. and waits while C. talks to other children.
1st girl tells C. she's going to the water

C. to Dana - " Have you seen a catfish today?"
Dana - "No"
C. - "Let's go and find one so you can compare with your picture"

white shirt boy has suction things to suck out specimens from jar - "monopolizing" - won't let other boy have it

look at bug on top of water in jar. C. asks children if they could do it (rest on surface of water). Children say no. C. says "I wonder how he does that." C. asks question...to make them think about it.
4 children around C.
2 at water

Diane wanders around, doesn't get involved very much. Carol gives her a jar of water to look at - boiled water compared to lake water

11:10
Carol goes to see students' drawings
Children explore what they want to with guidance and suggestions from C.

me - go to white shirt boy
- "Is that the specimen you just saw that you're drawing?"
boy - "Yes"
- (follows instructions well. Very "studious," involved quietly)

Diane using magnifying glass on jar of water. She gets up to look at children at water looking for catfish.

Boy from other group - "What did you guys catch today?"
Stan - "A gar pike."

C. says "feel this log"
other boy - "ooo-ooo, yuk!"

Diane asks what time it is

[end of observer's notes]

NB: 1st girl = Denise
boy in white shirt = Steve

APPENDIX J

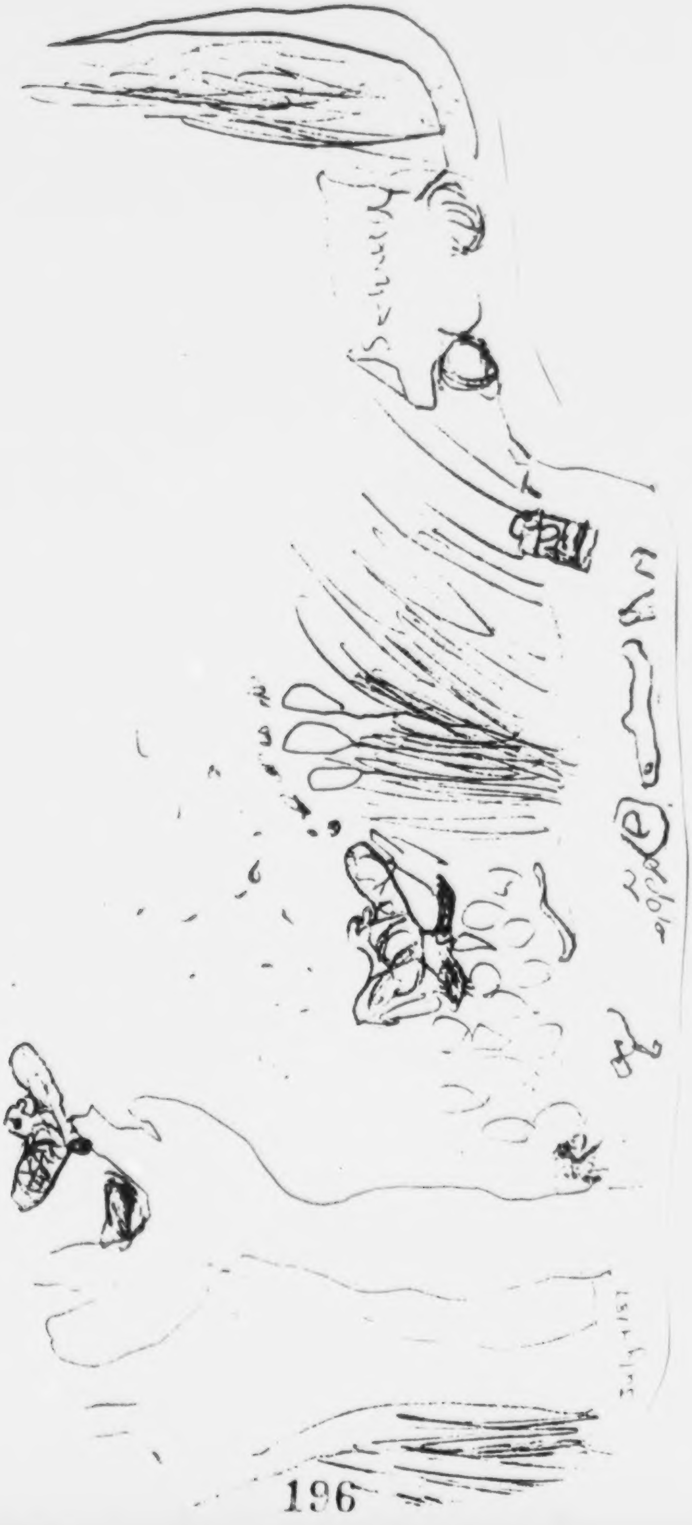
SUMMARY CHART OF OBJECTS DEPICTED IN STUDENTS' DRAWINGS

Objects Found in at Least One Drawing

	Diane	Denise	Dana	Scott	Steve	Stan
Plants						
lily pad	y		y	y	y	
cat tail	y	y		y	y	
				y		
duckweed		y				
roots	y	y				
seaweed	y	y				
reeds	y					y
grass					y	
Animals						
frogs	y		y		y	
turtle	y			y		
crayfish						y
fish	y	y	y	y	y	y
snail		y		y		
snake	y		y			
dragonfly		y	y			
birds				y		y
worms	y				y	y
shrimp				y		y
flies			y		y	
leeches			y			
Pollution					y	
garbage						y
sewage						y
Body Parts						
eyes	y	y	y	y	y	
ears			y			
legs		y	y			y
arms			y			
antennae			y			y
cilia	y	y		y		
mouth						y
gills				y	y	
stomach					y	
tail					y	
Other						
microbes				y	y	
green foam	y					
nest				y		
rocks	y			y		
person			y			
larva					y	

APPENDIX K

STAN'S DRAWINGS

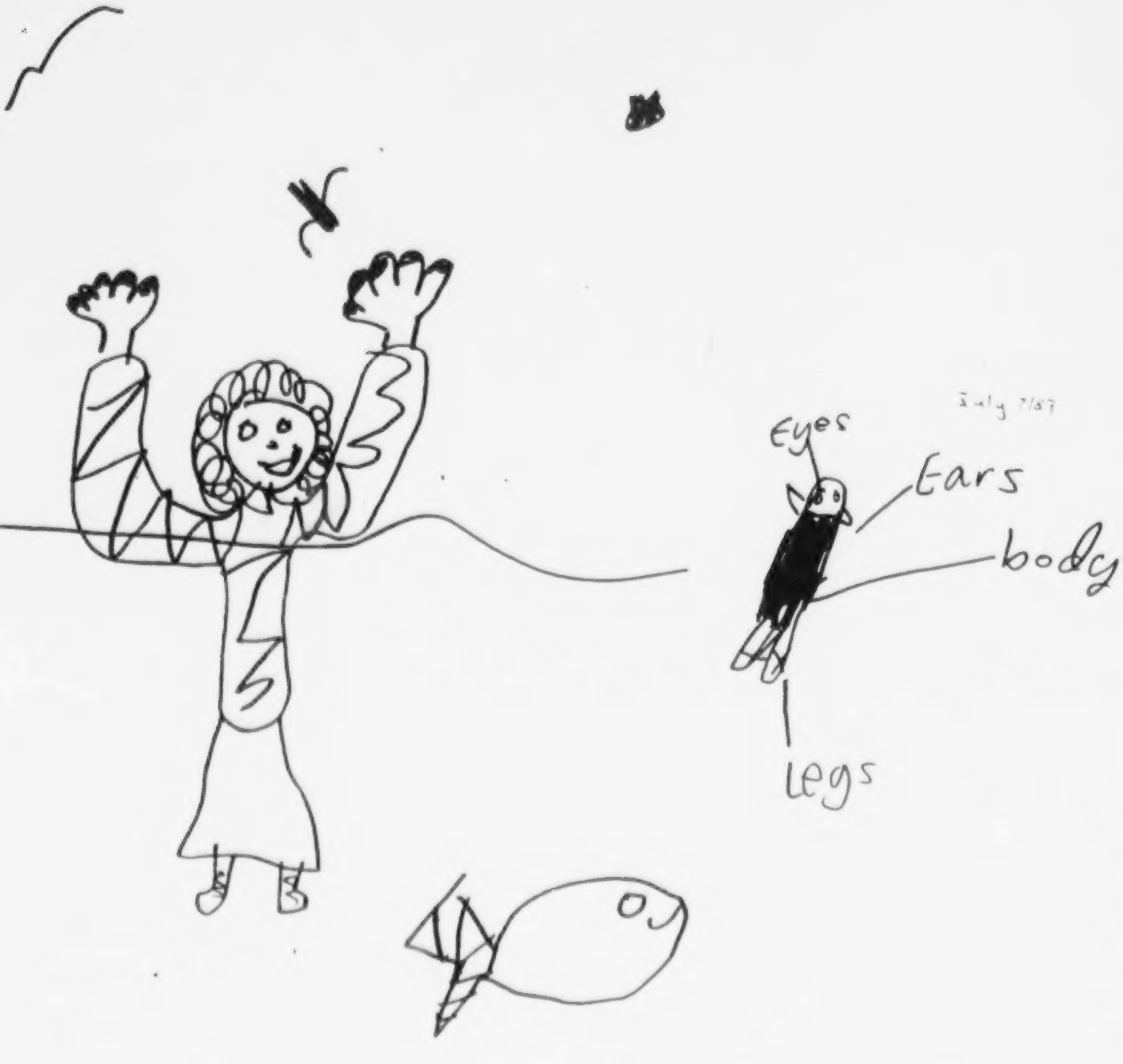


marsh
July 4/87
reeds
weeds
sew-ag
pollutea water
sewer
July 7/87
legs
Antonne
head
curling Shrimp

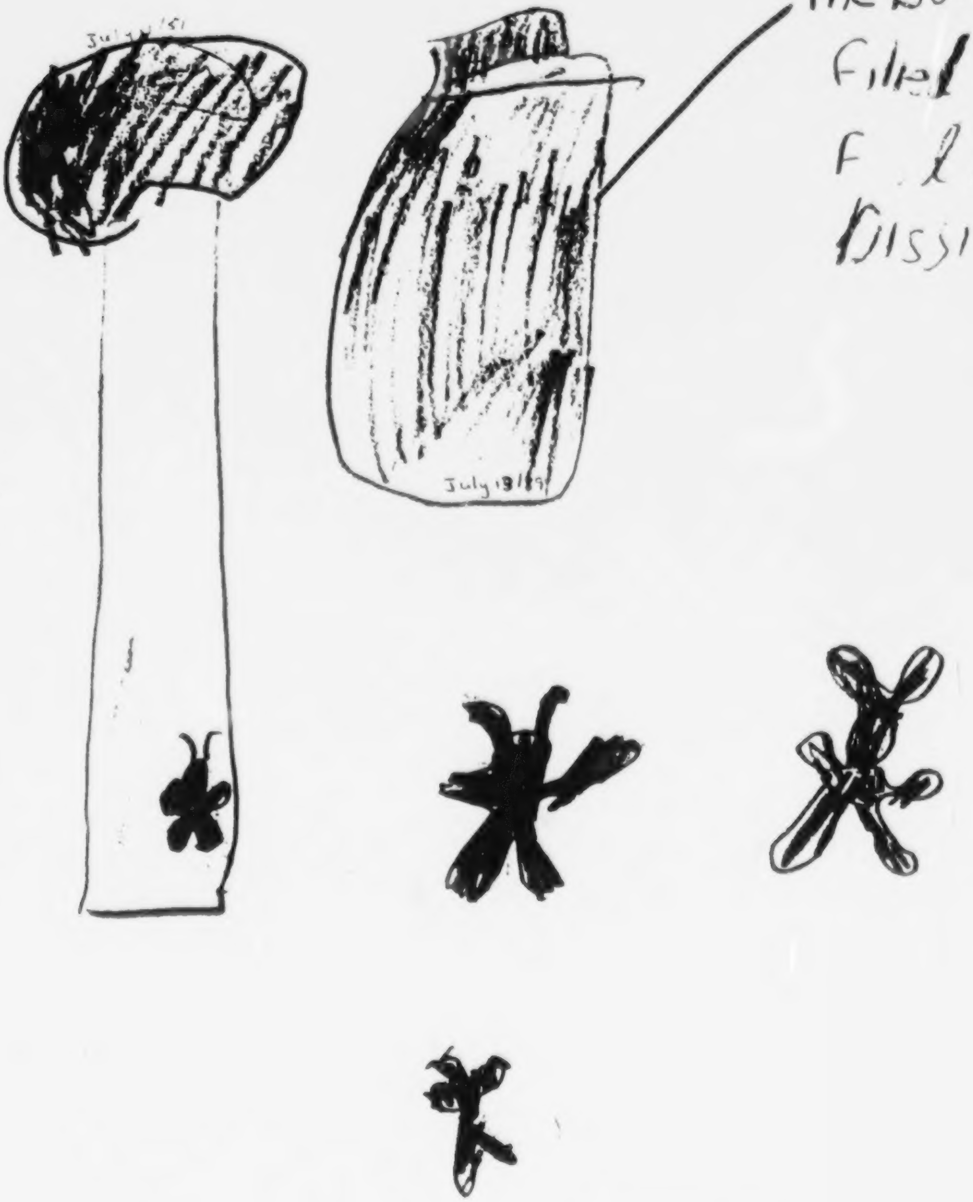
crayfish
August 13/87

APPENDIX L

DANA'S DRAWINGS

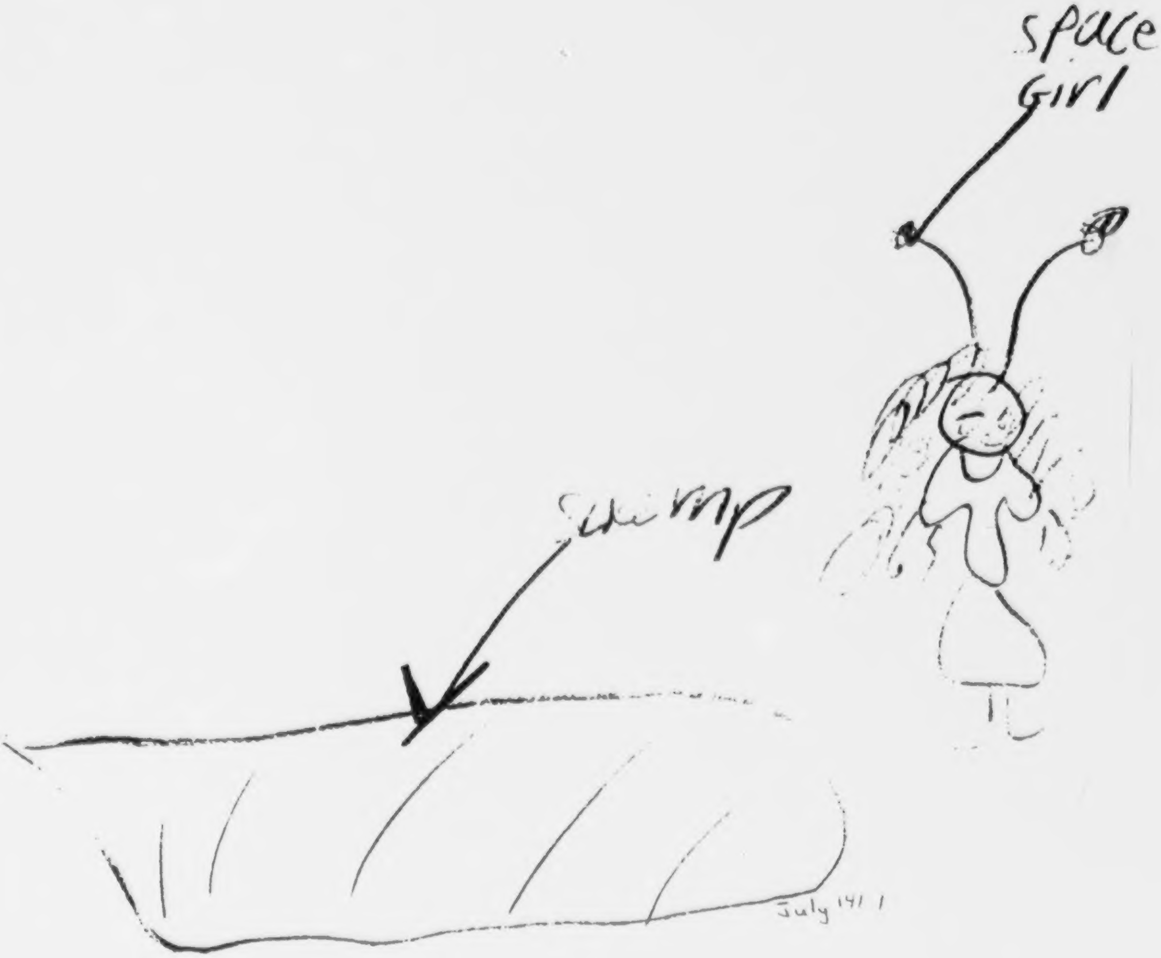


Green Fromming Stuff

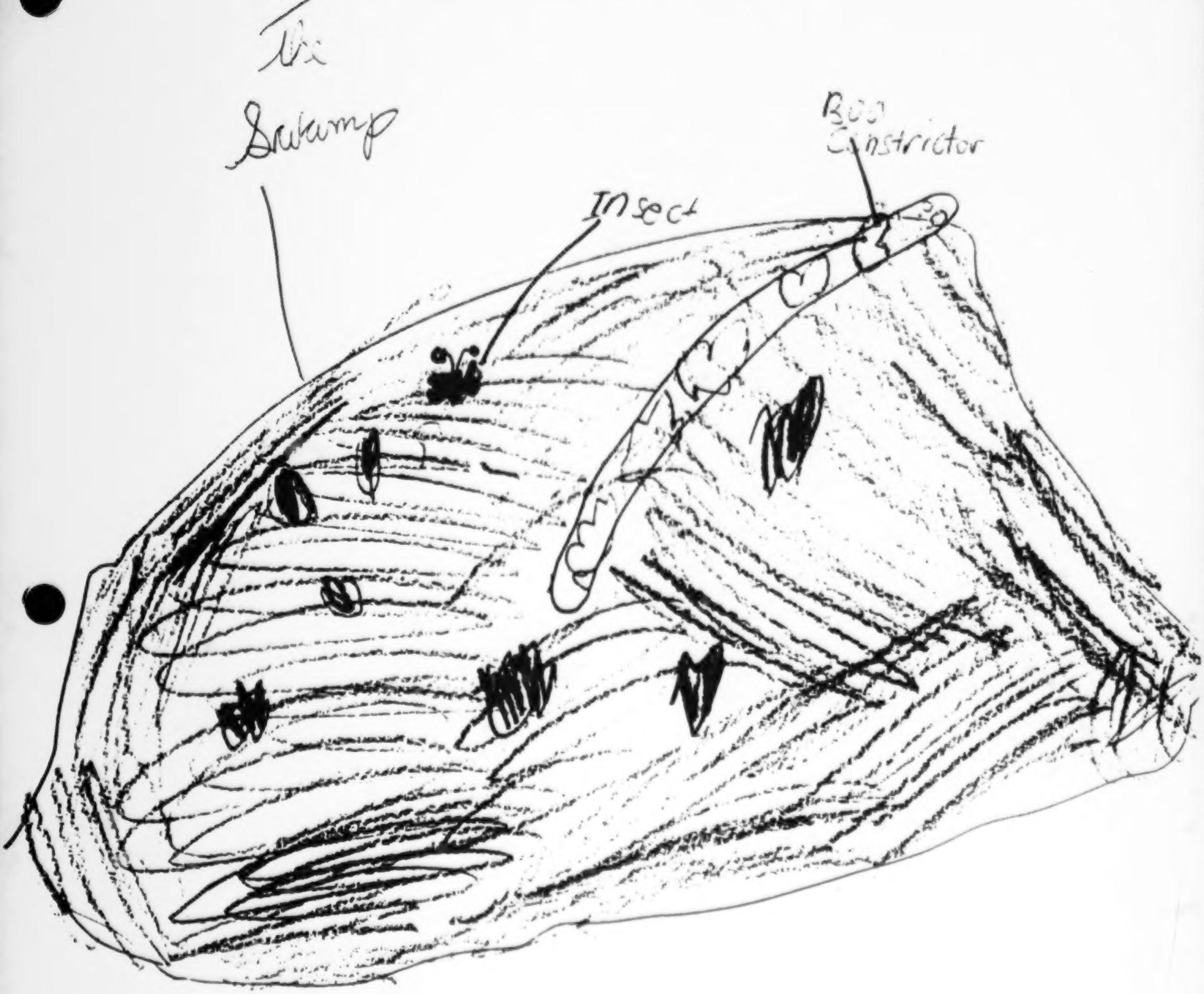


the Bottle that I Filled With green Food Coloring to Dissivelled

This is a Dragon FLY Nip



July 1971



A Swamp is sort of like a Wet Land Area!

The inside of a Leach

VITA

Name: Carol Marie Hulland

Birth: Canada, 1960

Education:
Queen's University, 1979-81.
University of Guelph, 1981-83.
B.Sc. (agr., honours) 1983.
University of Toronto, 1984-85.
B.Ed. 1985.
Queen's University, Summer 1986, Ministry of Education Course, Special Education, Part I.
Queen's University, 1988-1990.
M.Ed. (curriculum studies) 1990.

Experience:
Elementary teacher, K-gr.8, music and general, Metropolitan Separate School Board, 1985-1988.
Science curriculum development team, M.S.S.B., 1987-1988.
Science curriculum development team, Ontario Ministry of Education, August 1988.
Research Assistant, Queen's University Faculty of Education, 1988-89.
Elementary teacher, gr.2-6, music and general, Hastings County Board of Education, 1989-present.

Awards: Graduate scholarship, Queen's University, 1988-89.

Publications:
(With M. O'Keefe, A. Bertoli, D. Carey, E. Chiminello Lelli, P. Crawford, P. Husarewych, T. Laphen, & R. Oswald) Science: Exploring Our World, Curriculum Resource Document for the M.S.S.B., Toronto, Ont., September 1987.

Contradictory Principles in Elementary Science Documents: A Critique. Paper presented at the meeting of the Canadian Society for the Study of Education (C.S.S.E.), Quebec City, Quebec, June 1989.

Children's Changing Perceptions of Science Concepts: A Qualitative Study in a Swamp. Paper presented at the meeting of the C.S.S.E., Victoria, B.C., June 1990.

Appendix 16

END

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Date Filmed

March 29, 1991